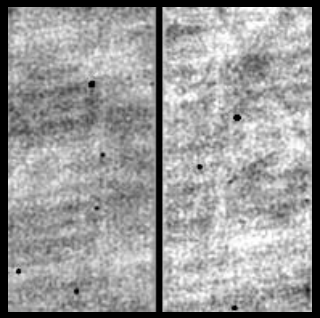
# Tree Ring on LSST CCD

Yuki Okura

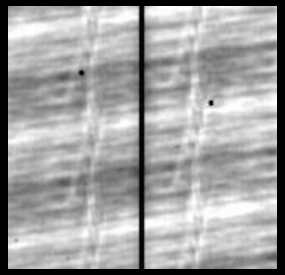
- e2v CCD

- wave length 750nm

Shorter wave length images have stronger strange pattern.
Longer wave length images have stronger fringes.



750nm



450nm

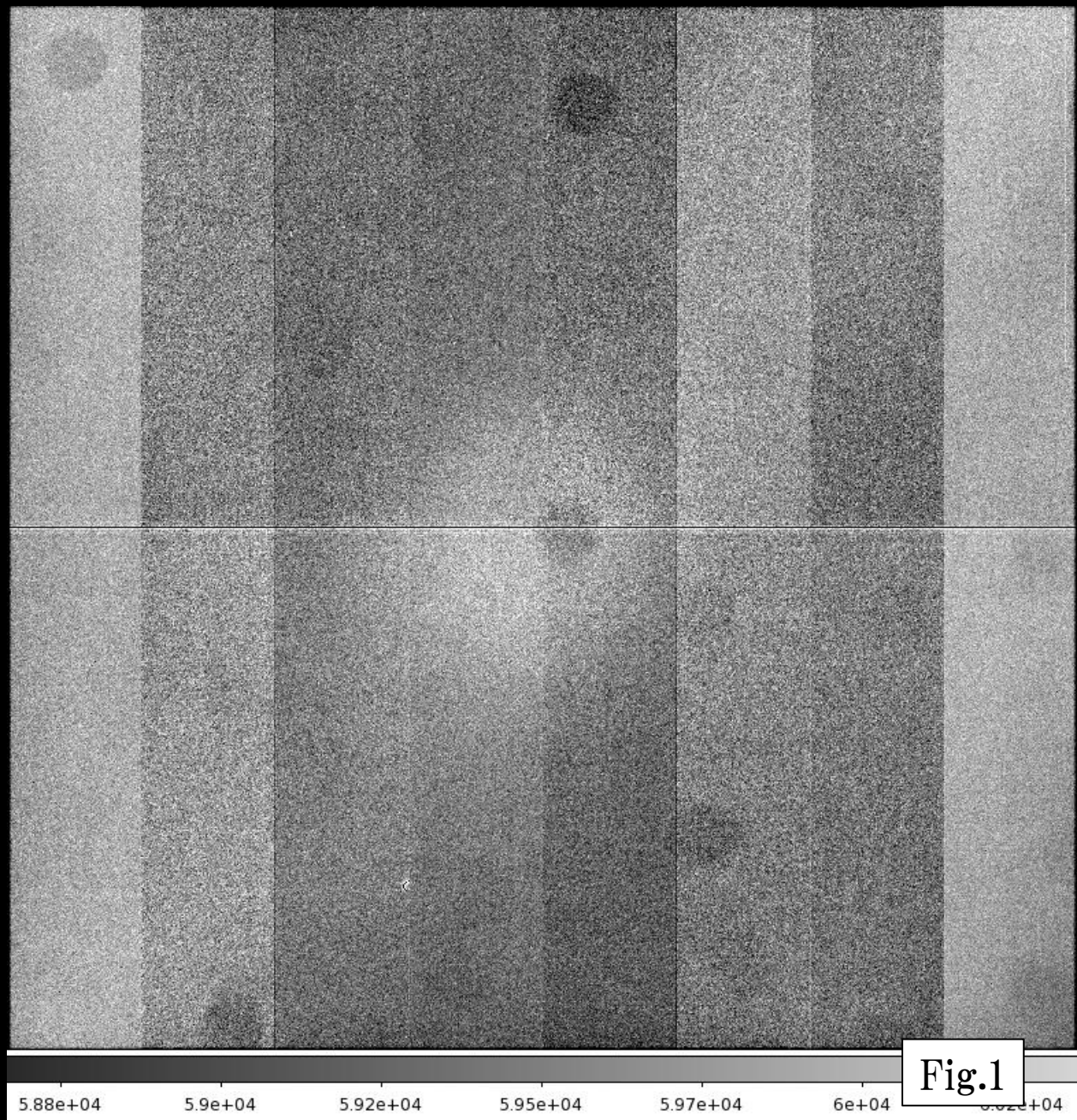



Fig.1

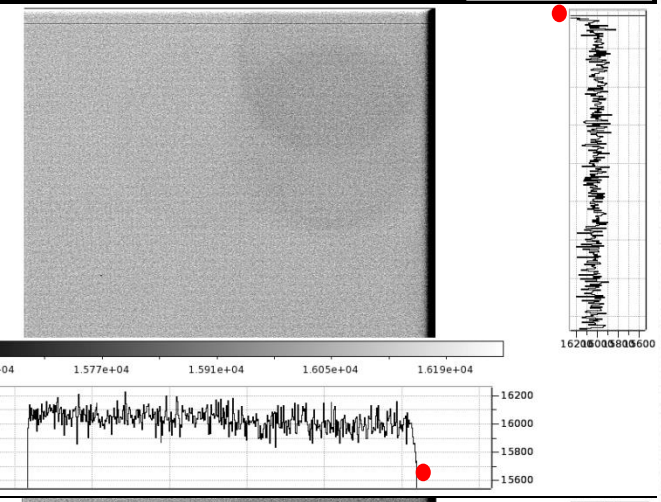
# Steps for Measuring Tree Ring Patterns

- Stacking
- Masking
- Polynomial fitting and normalization
- Correcting other patterns
- Determining Tree Ring Center
- Measuring Tree Ring Pattern
- Testing Tree Ring Cancelation
- Calculating Displacement by Tree Ring
- Calculating Spurious Shear by Tree Ring

# Masking

- Masking edge of each channels (red)

Fig.2-2



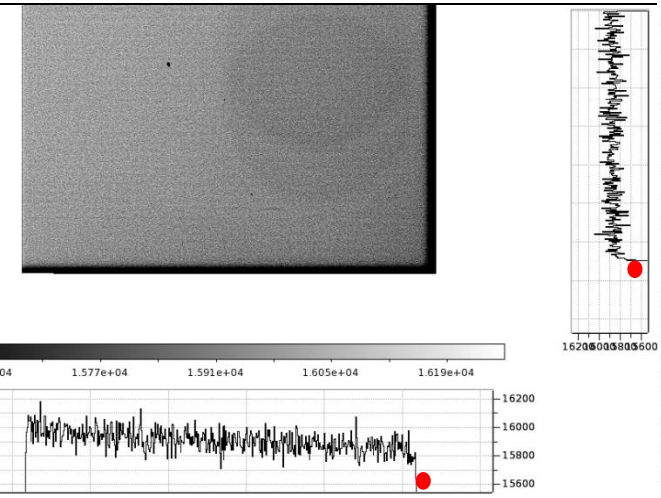




Fig.2-3

- masked(white) region = nan

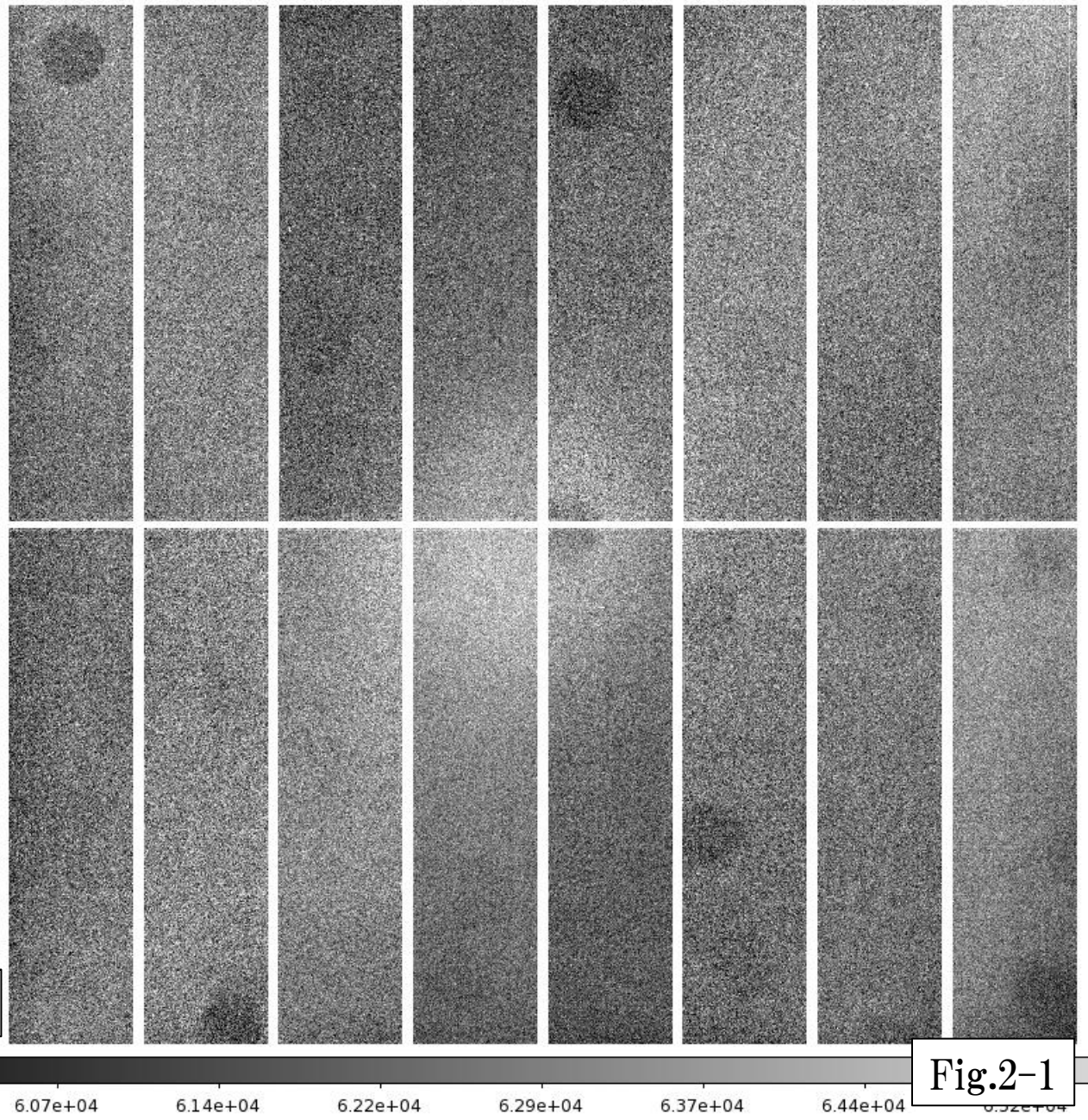



Fig.2-1

# Masking

- Masking lower count regions by shadows (red)

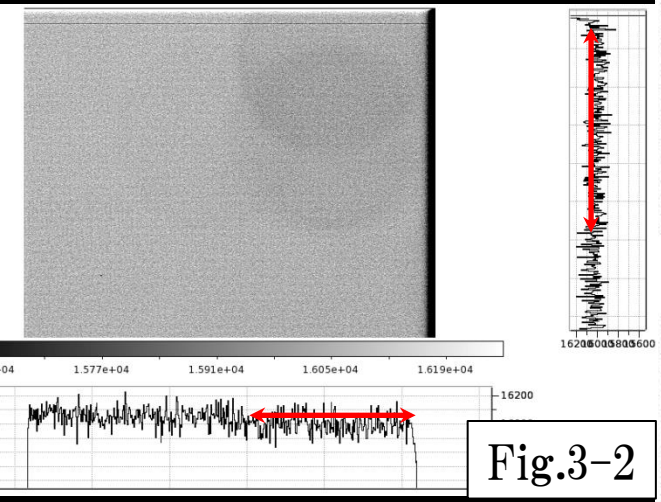



Fig.3-2

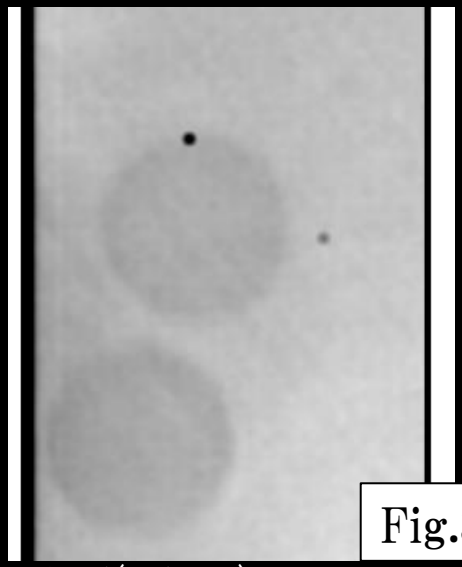


Fig.3-3

- masked(white) region = nan

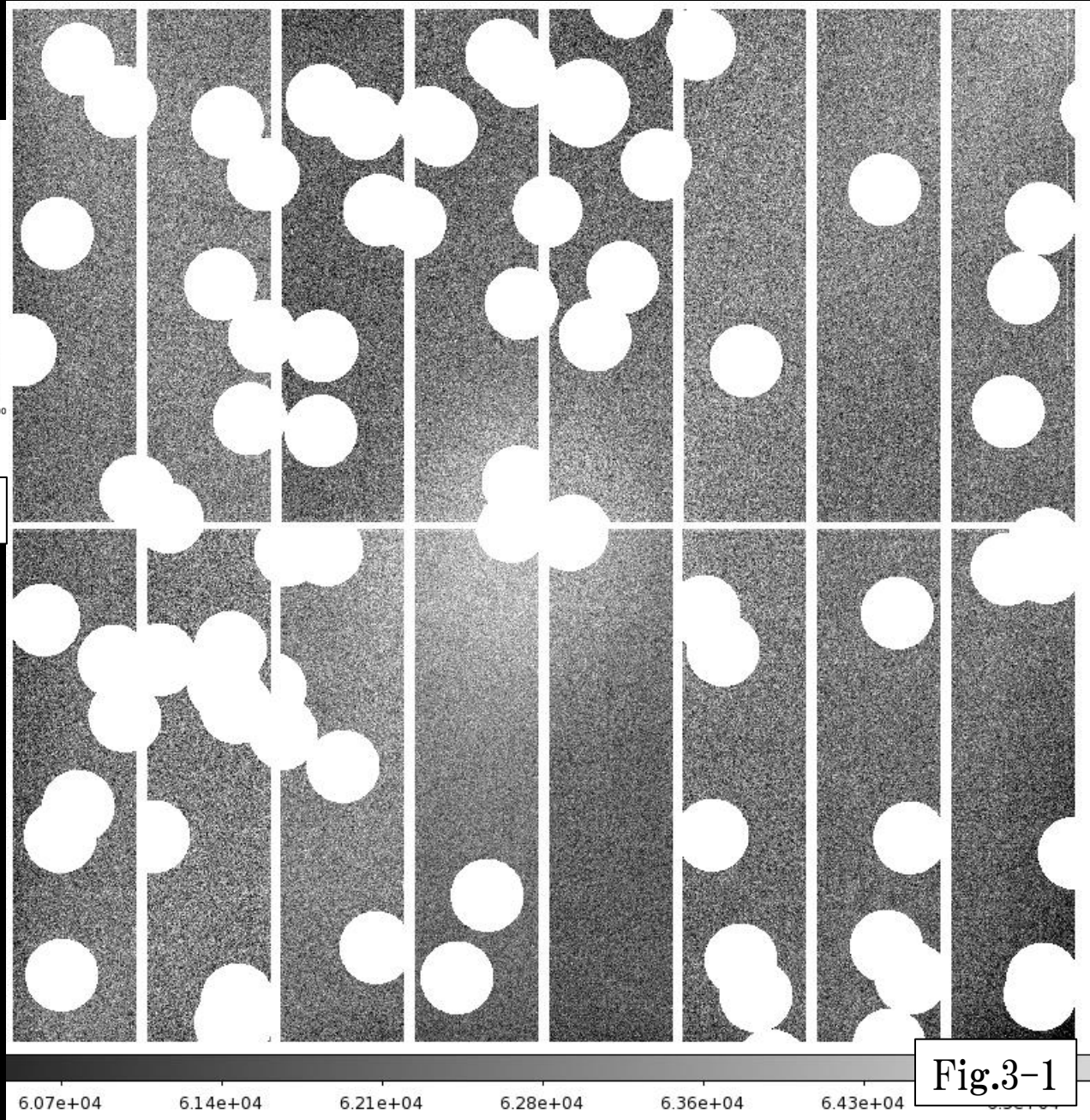



Fig.3-1

# Polynomial fitting and normalization

- $7^{th}$ order polynomial fitting for each channels and normalize.

- AVE = 1.0
- STD = 0.004

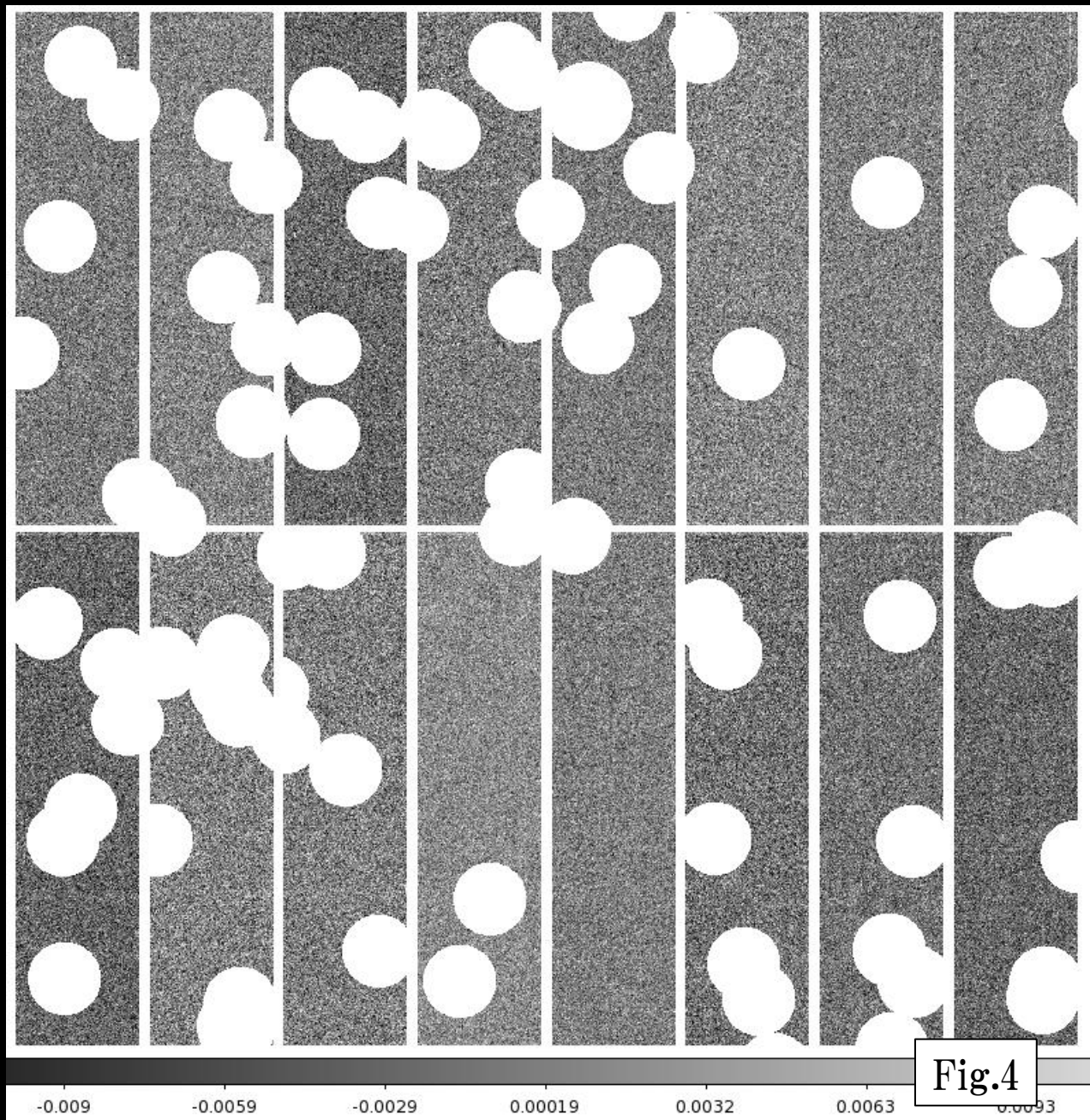



Fig.4

# Polynomial fitting and normalization

- Tree Ring can be seen from smoothed image.

- some other patterns which don't look like tree ring are visible.

- grid pattern(pixel size?)

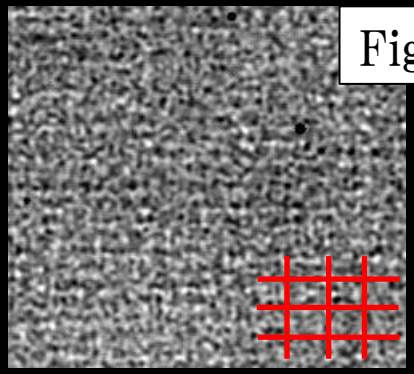


Fig.5-2

- sloped line pattern(?).

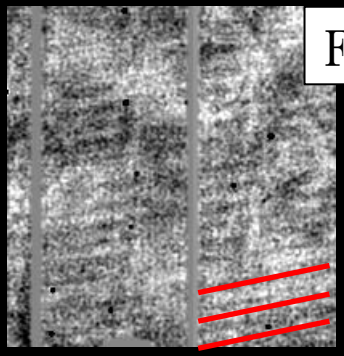


Fig.5-3

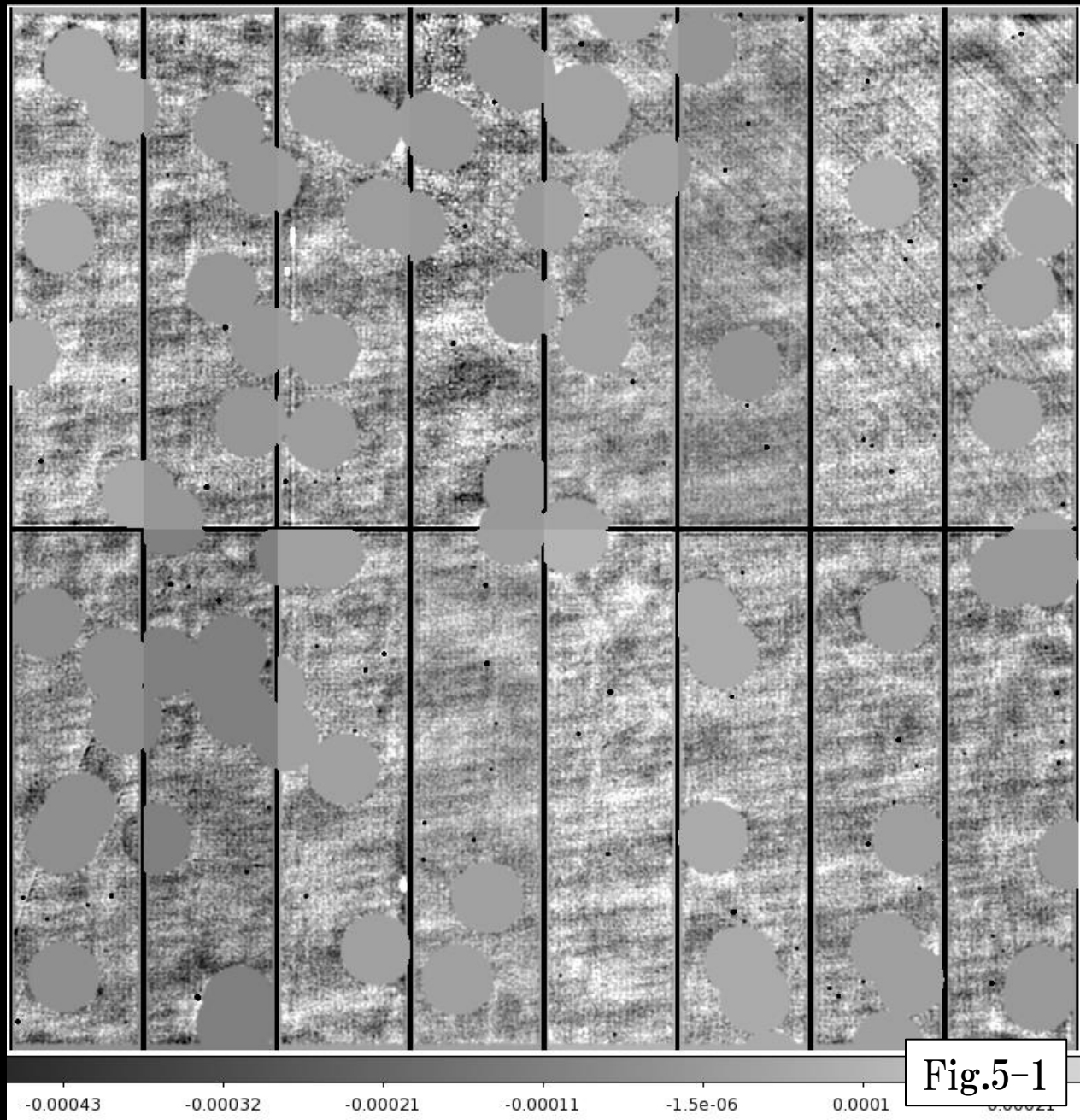



Fig.5-1

# Correcting other patterns

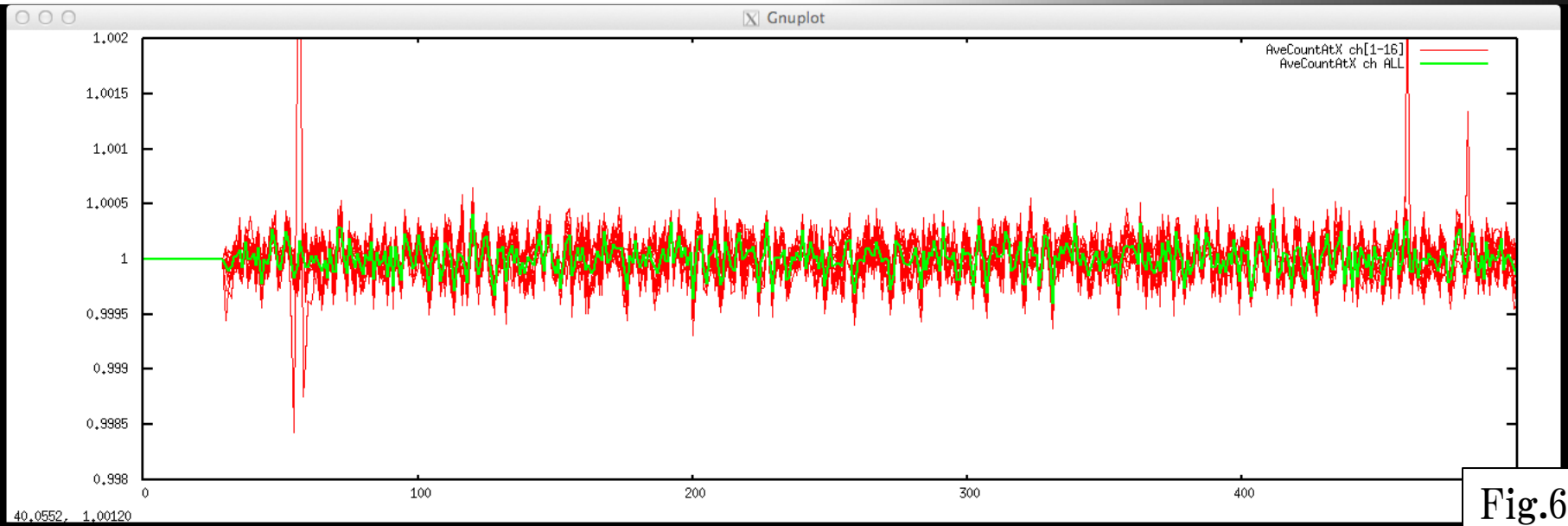



Fig.6-1

Average counts vertical lines

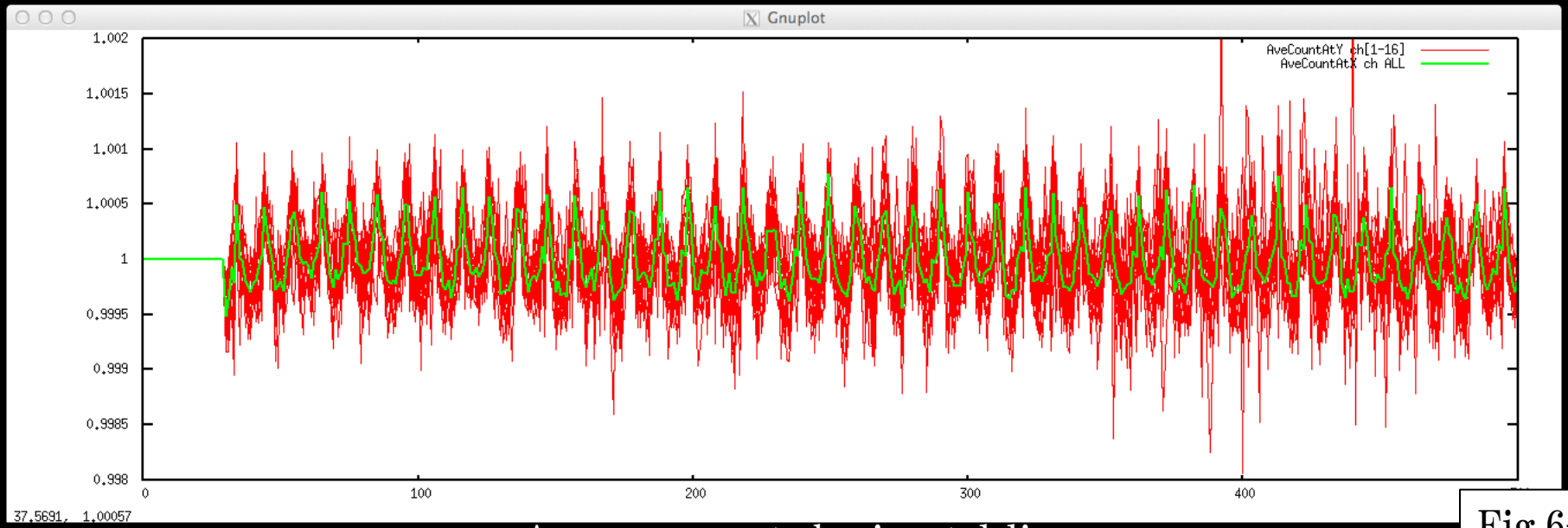



Fig.6-2

Average counts horizontal lines

# Correcting other patterns

• Normalization by the grid pattern.

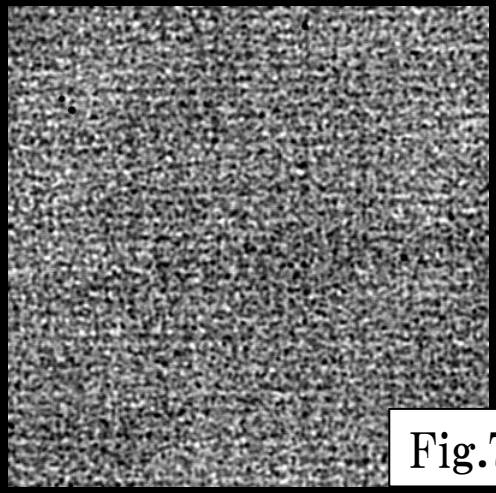


Fig.7-2

Before correction

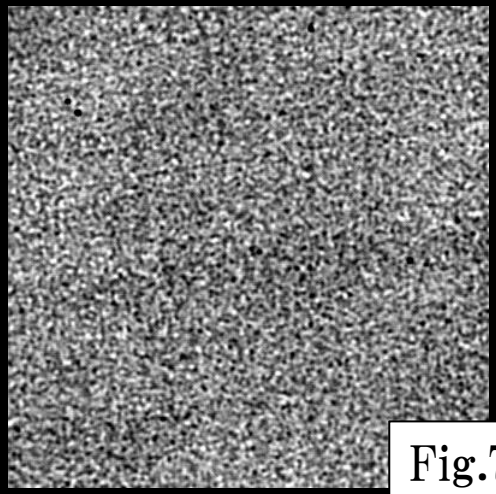


Fig.7-3

After correction

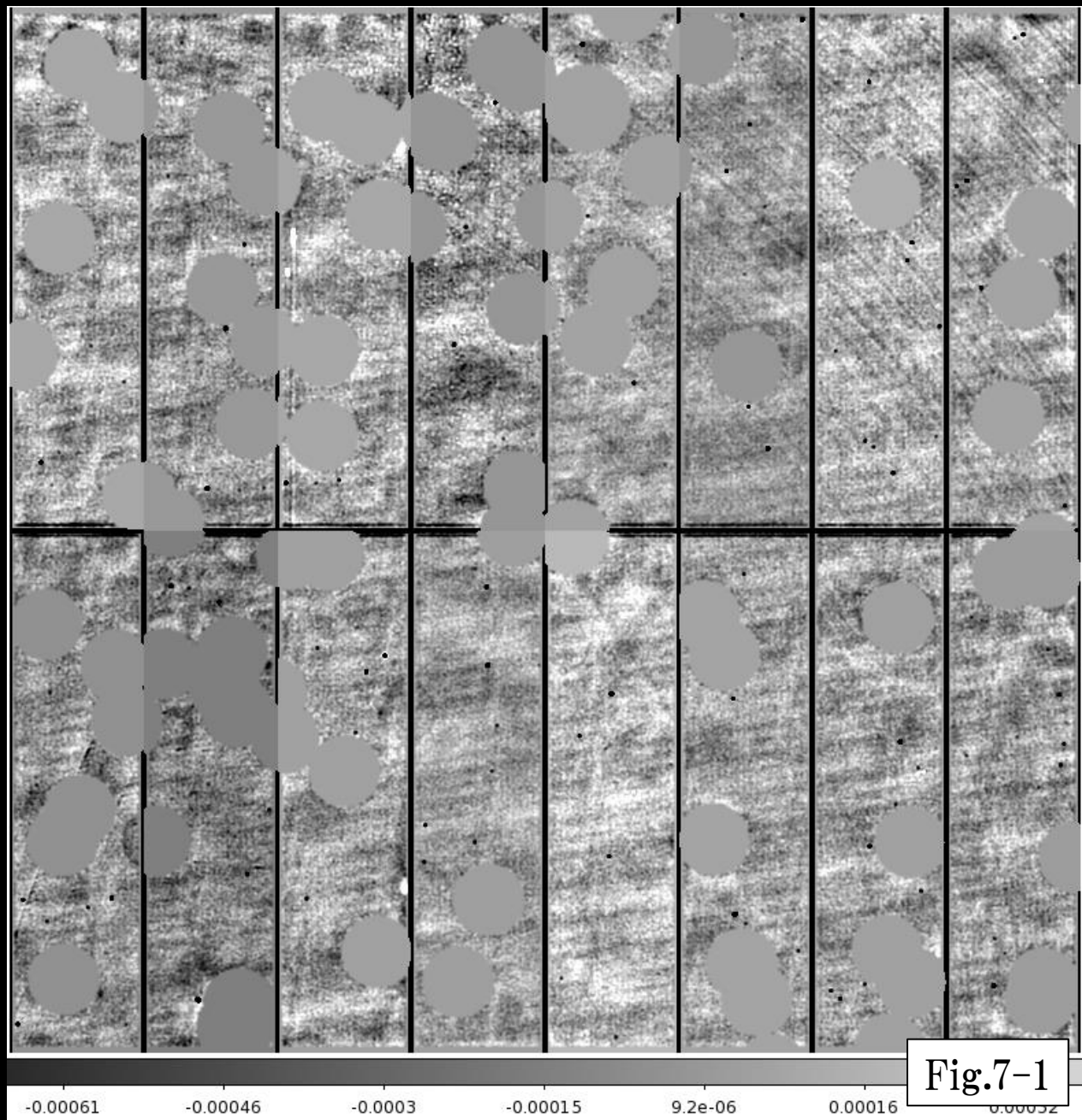



Fig.7-1

# Correcting other patterns

- Lines of the slopes can be fitted by y = 0.15x.

- fitting each lines and normalize

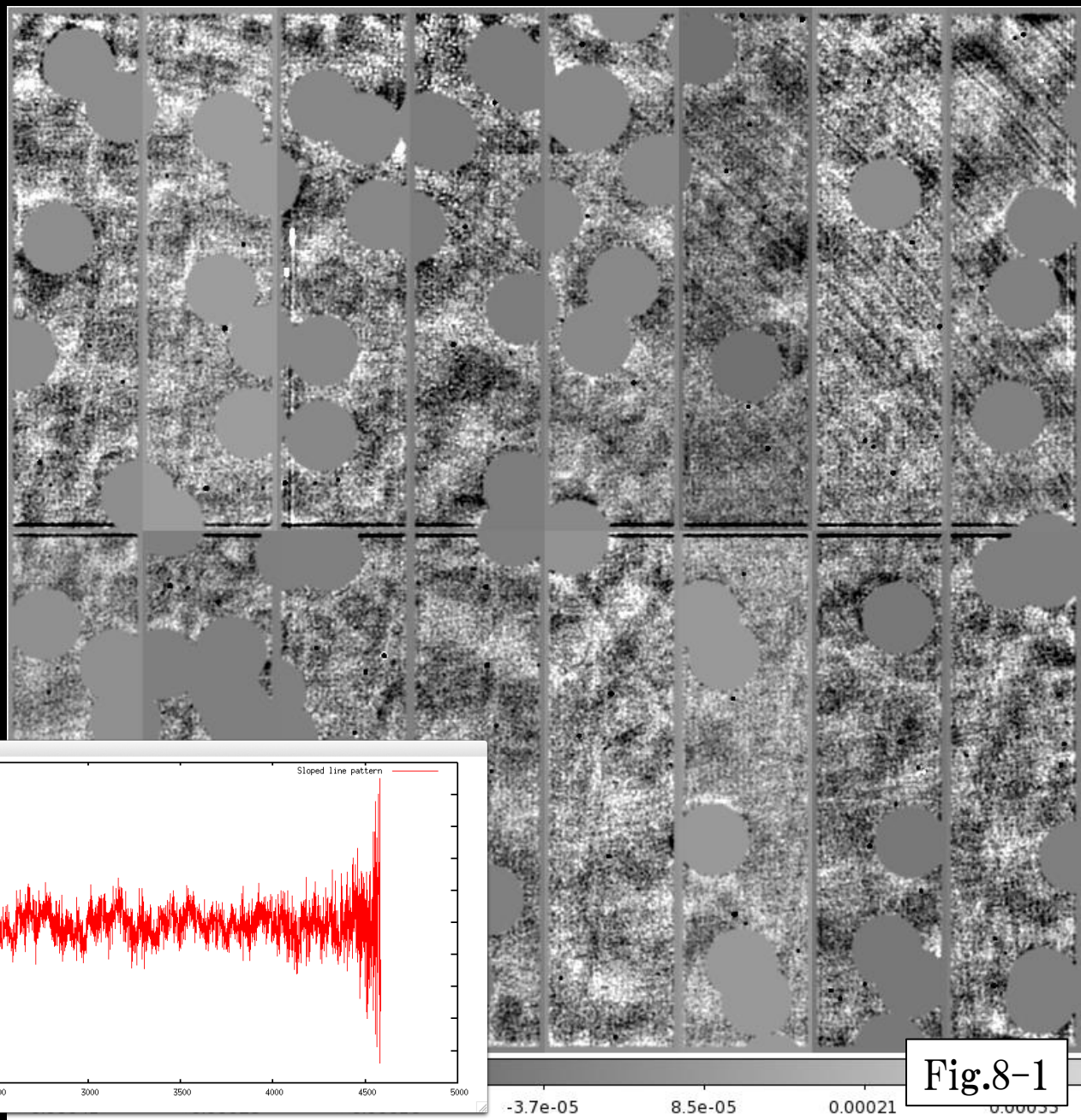



Fig.8-1

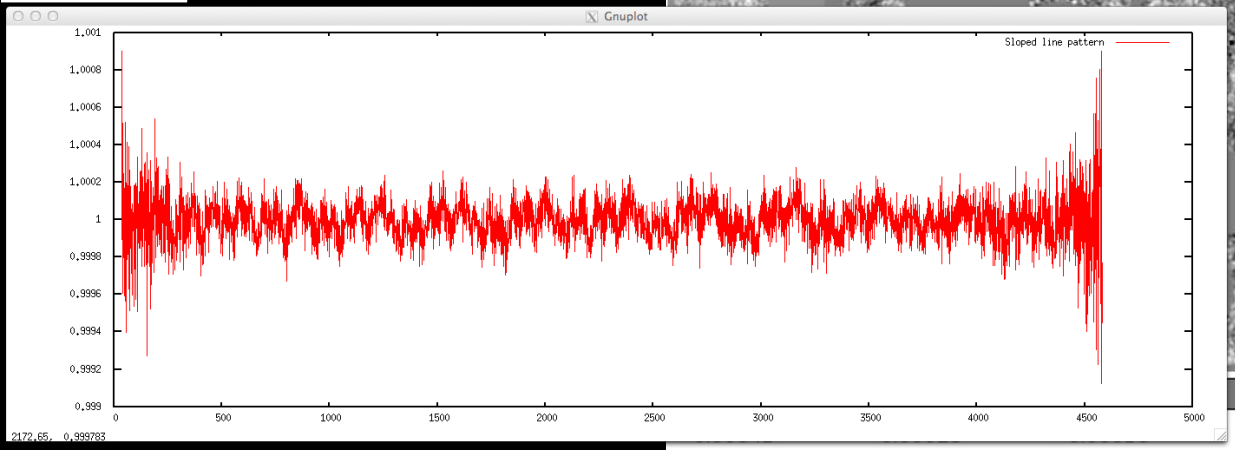



Fig.8-2

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. No subtraction

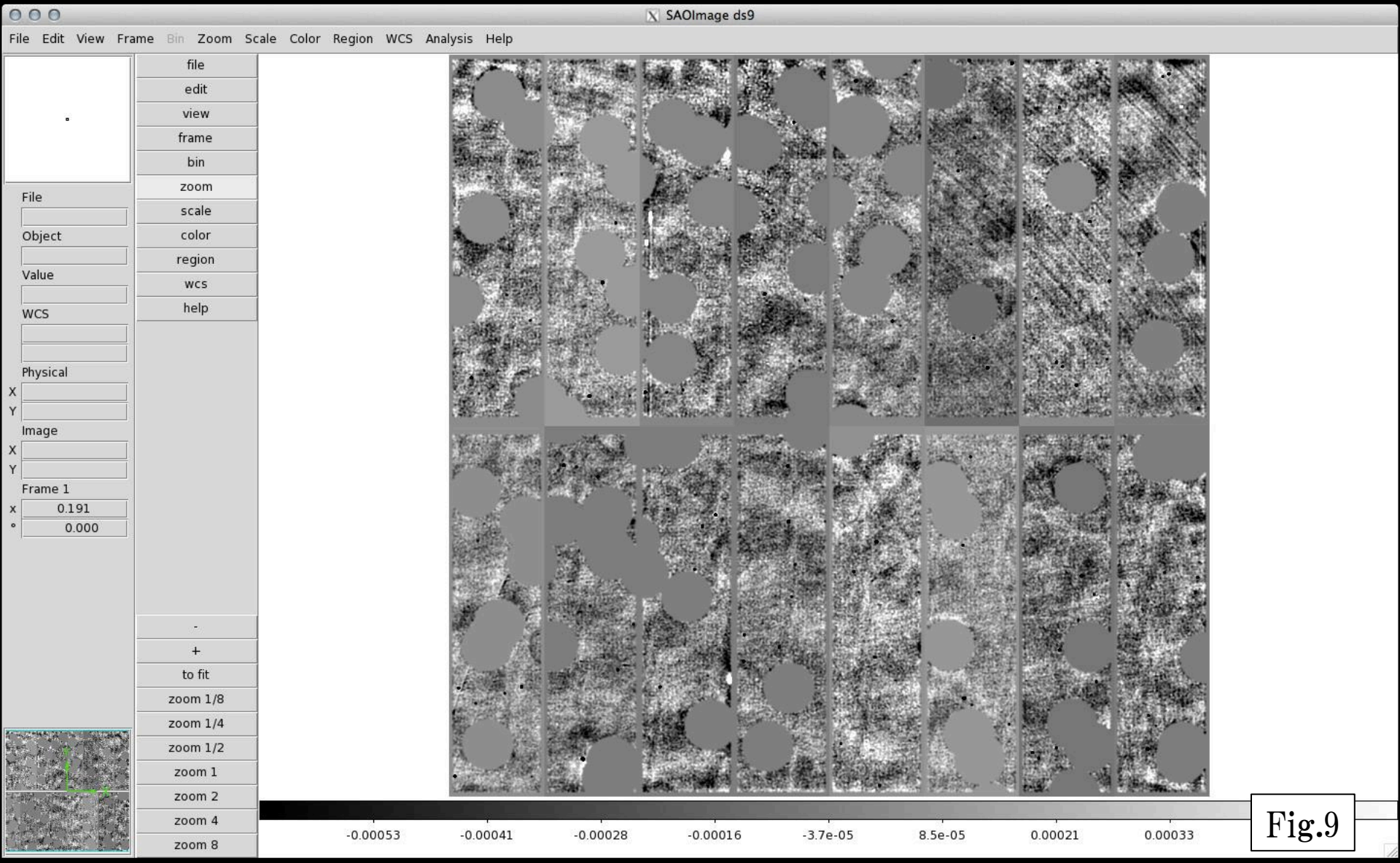



Fig.9

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 1 and |ky| <= 1

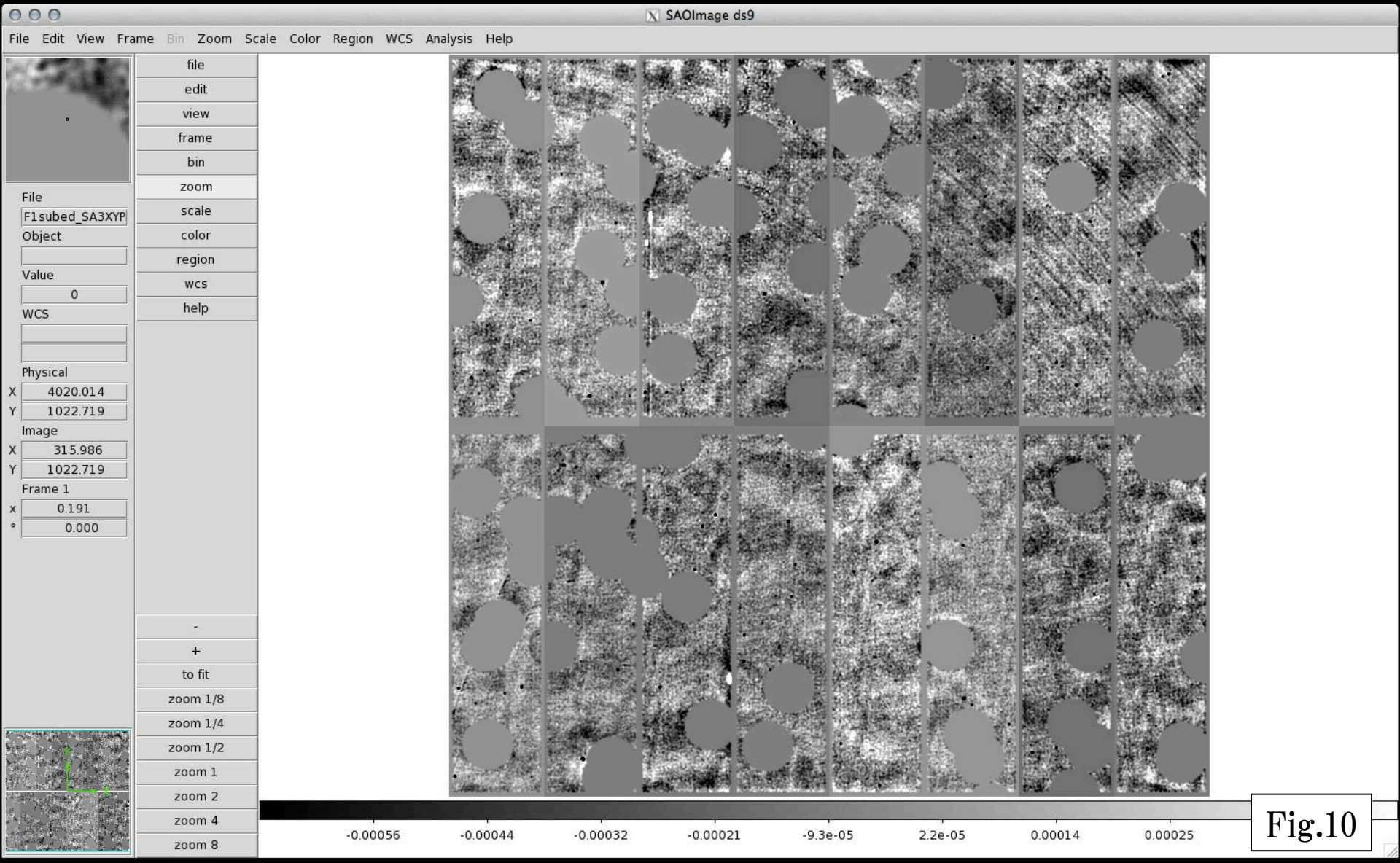



Fig.10

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 2 and |ky| <= 2

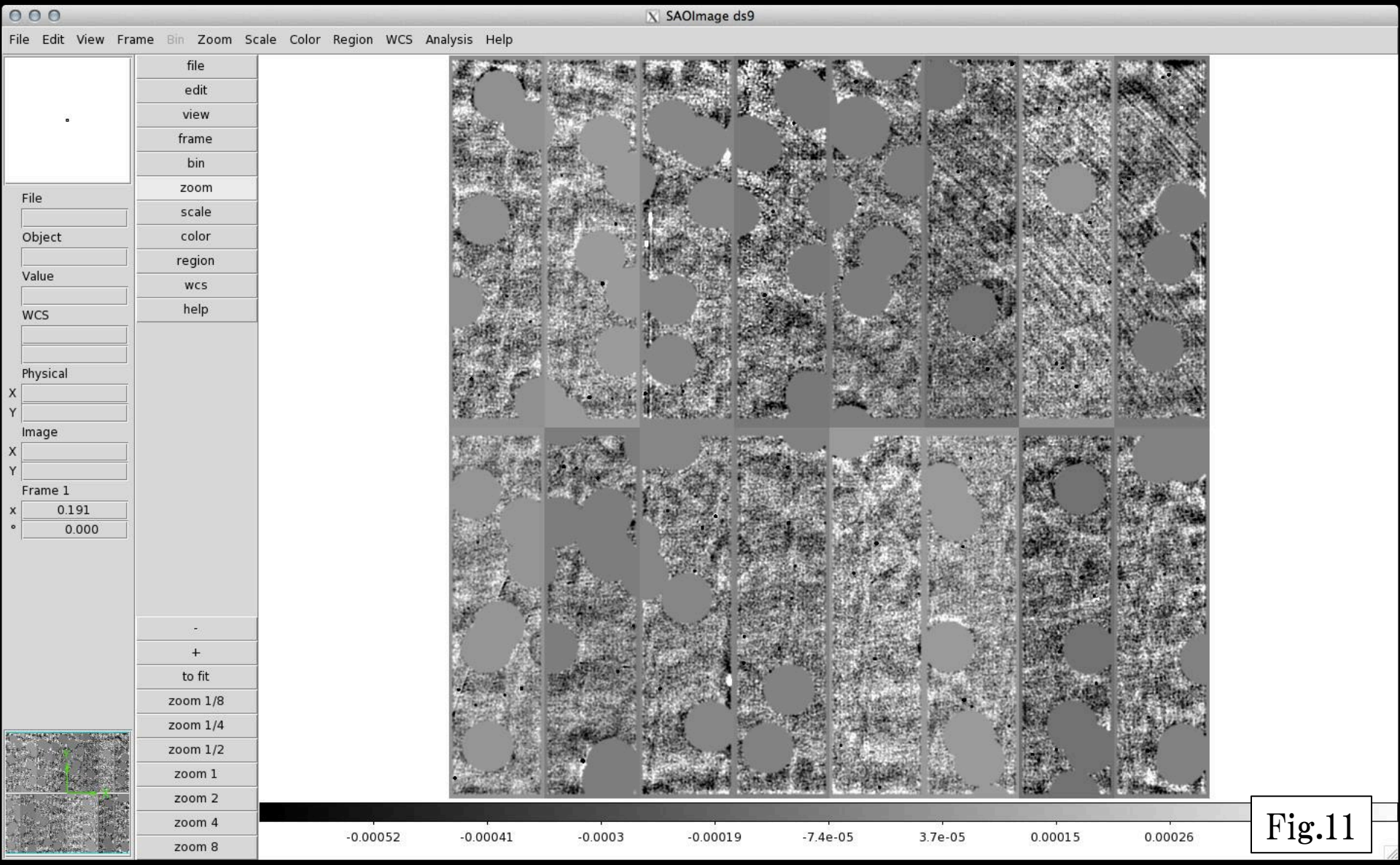



Fig.11

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 3 and |ky| <= 3

Fig.12

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 4 and |ky| <= 4

Fig.13

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 5 and |ky| <= 5

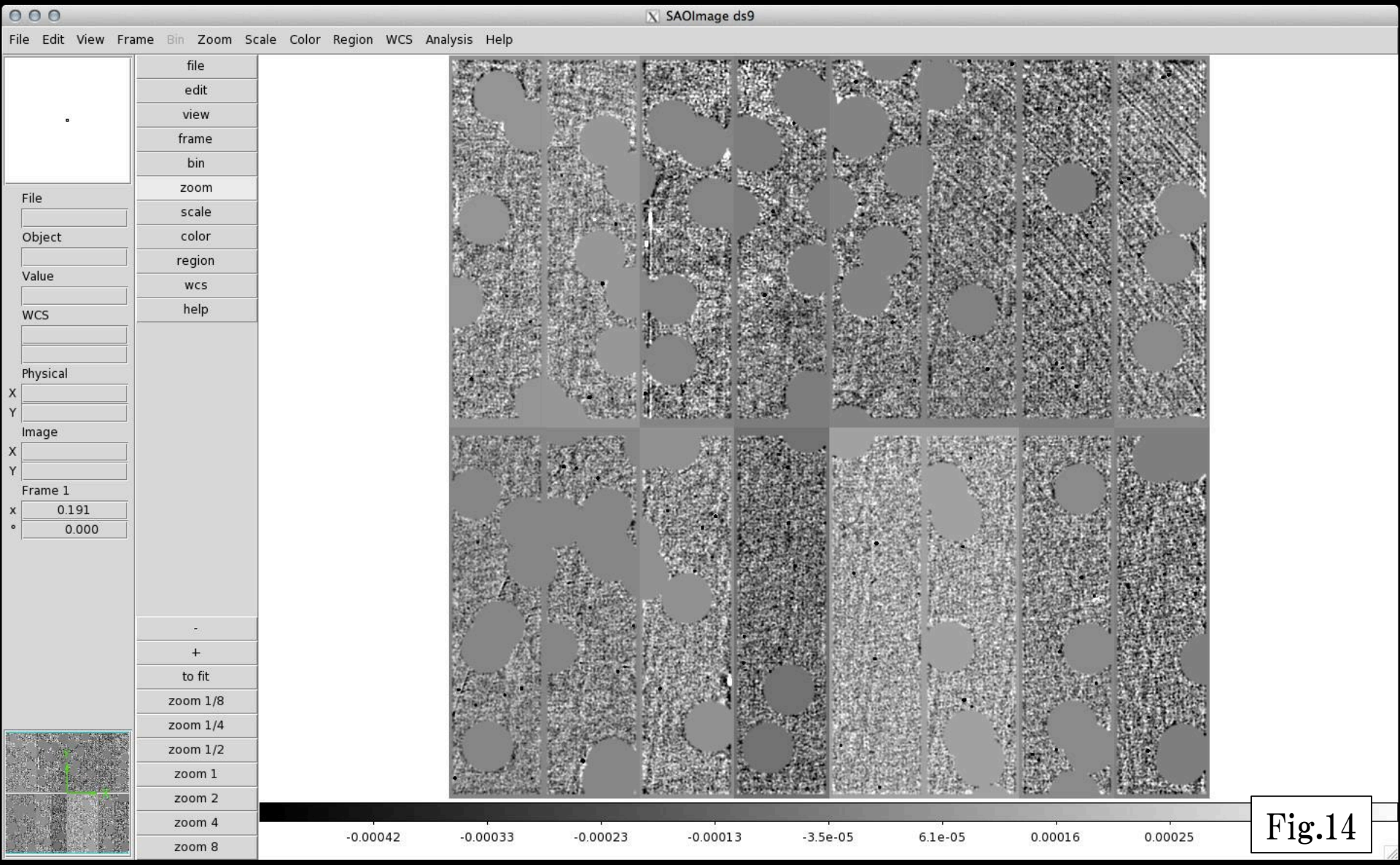



Fig.14

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 6 and |ky| <= 6

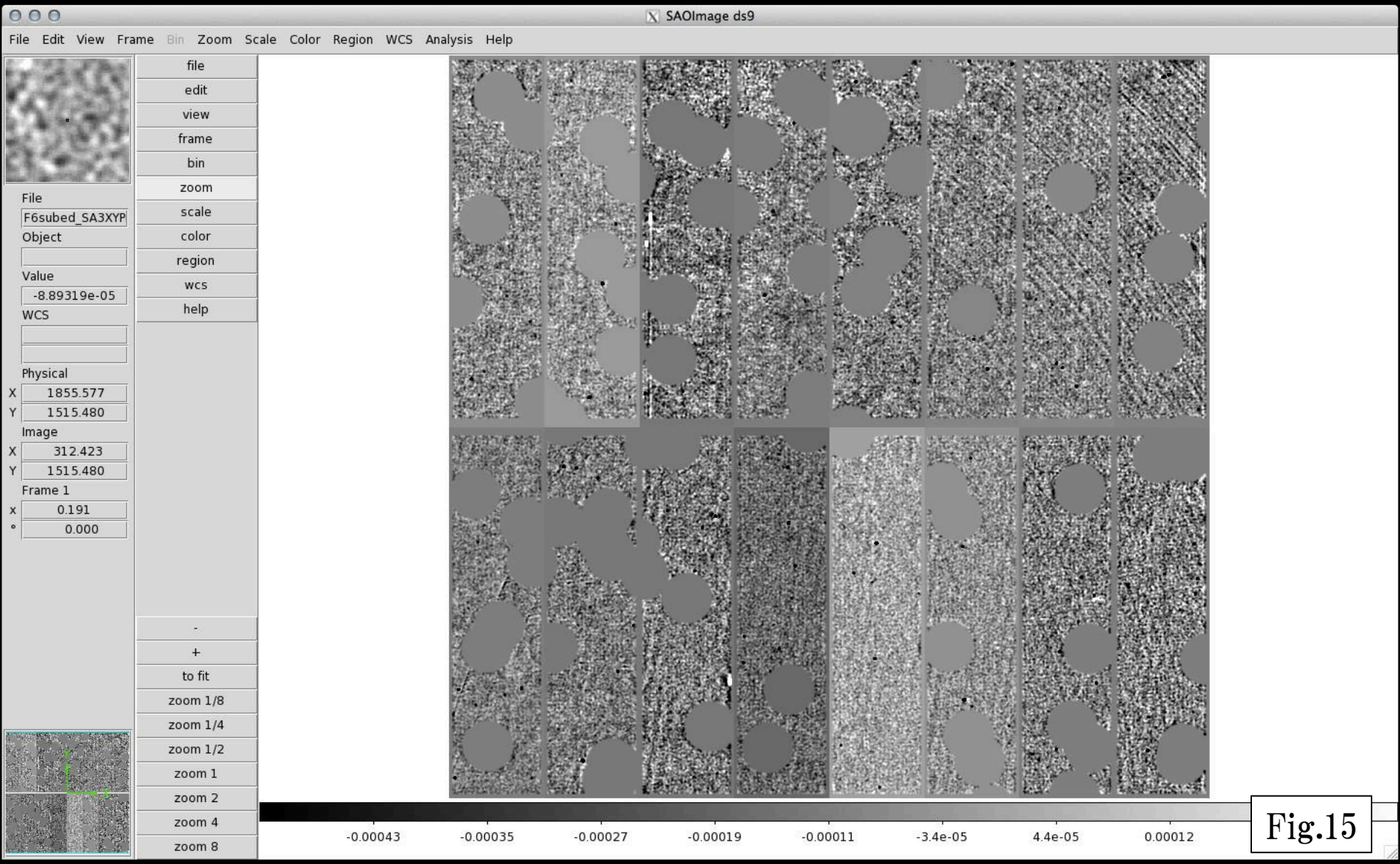



Fig.15

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 7 and |ky| <= 7

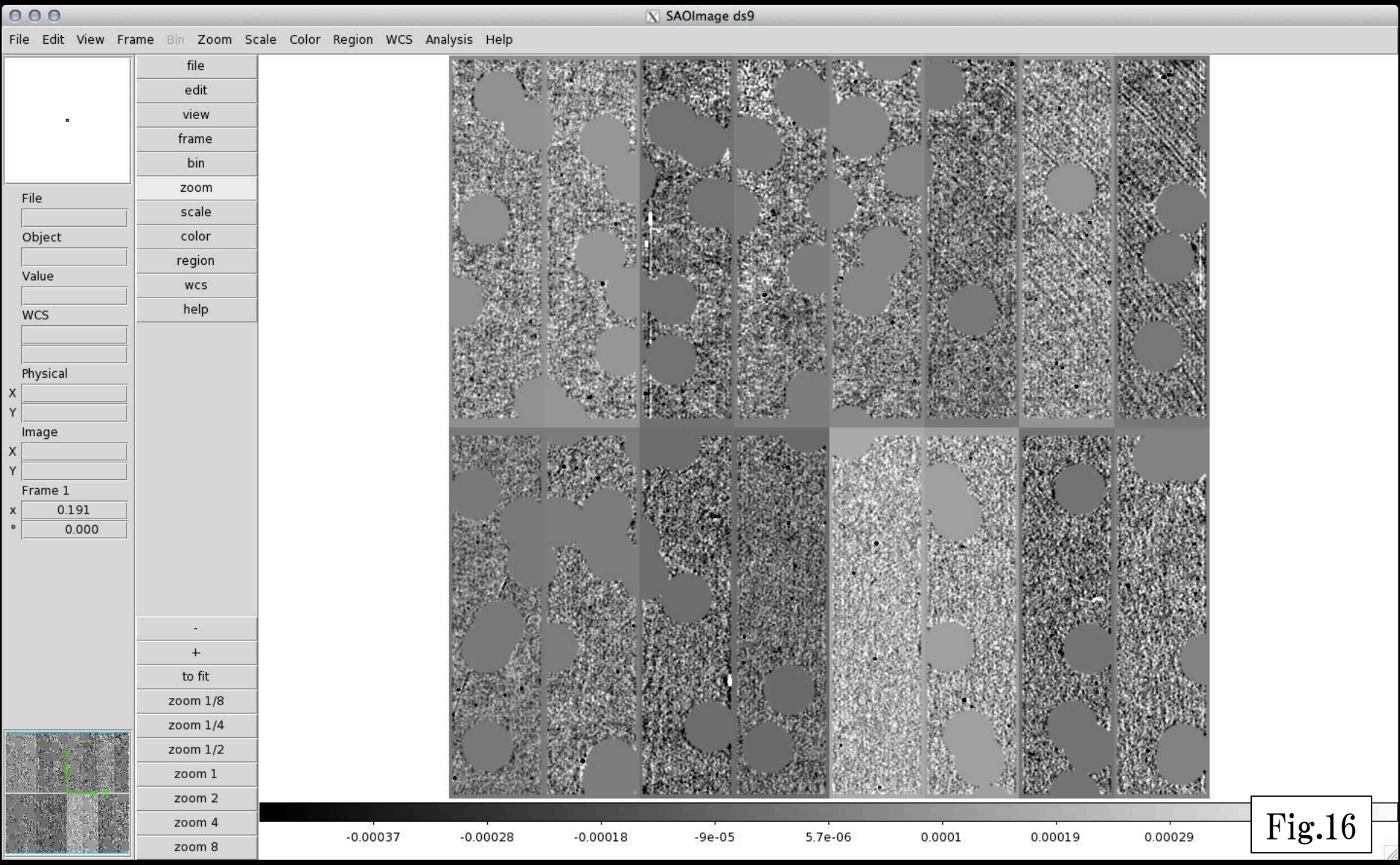



Fig.16

# Correcting other patterns

- large scale fluctuation subtraction in Fourier space. Subtraction |kx| <= 8 and |ky| <= 8

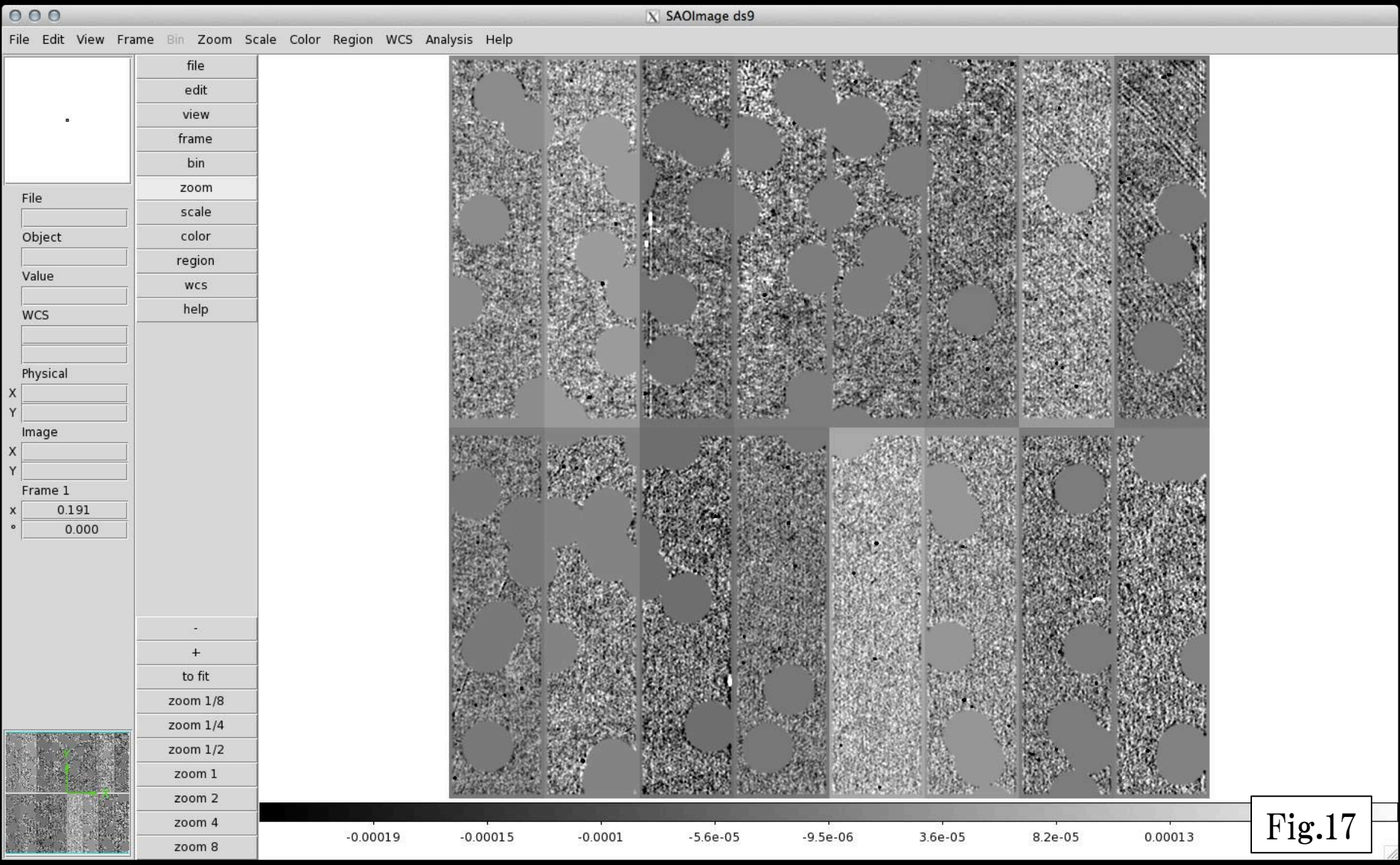



Fig.17

# Determining Tree Ring Center

- Measuring positions of lines of tree ring and getting center of the ring by least square fitting.

- (Temporary) Center [4575, -375]

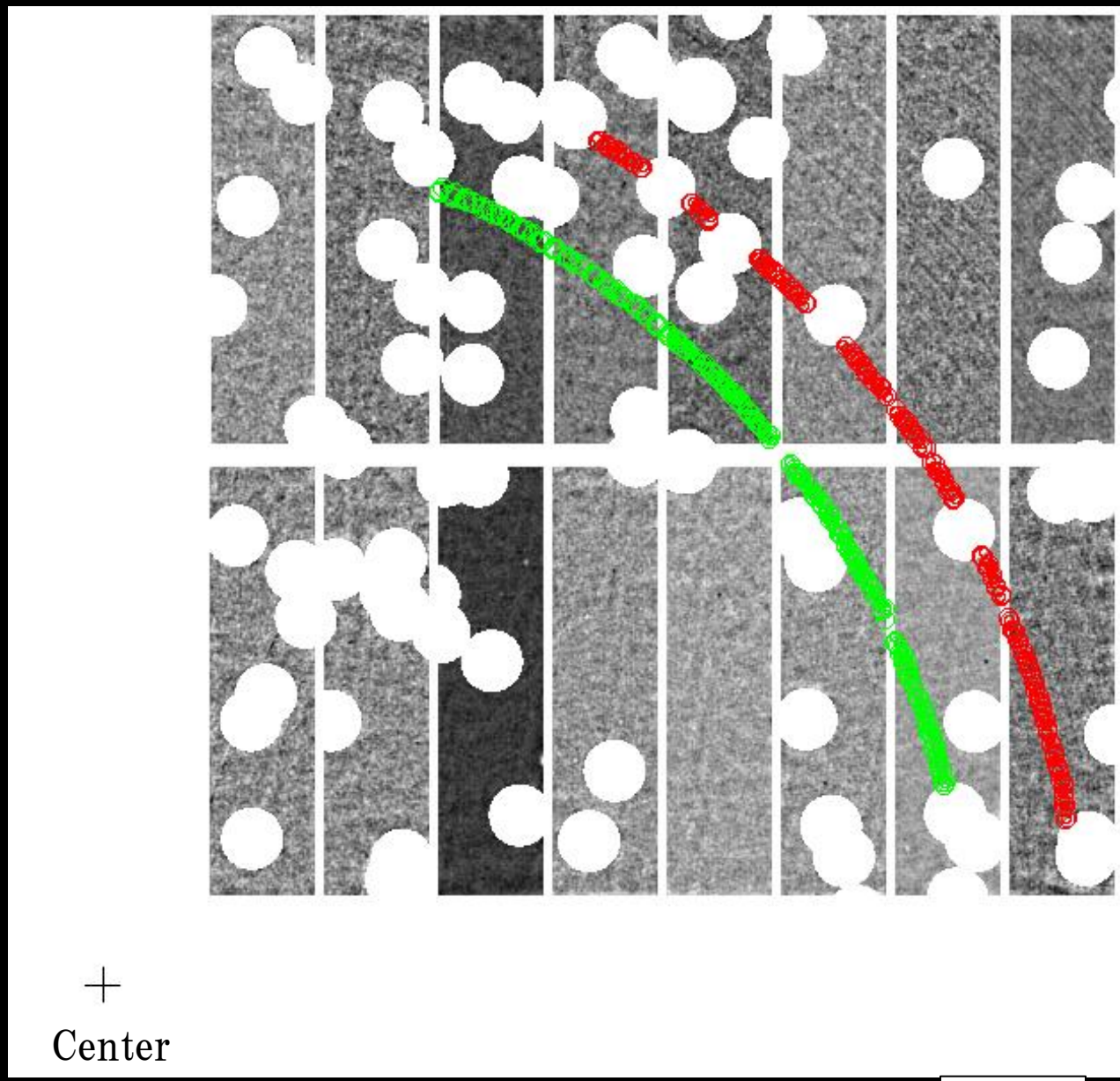



Fig.18

# Determining Tree Ring Center

- 

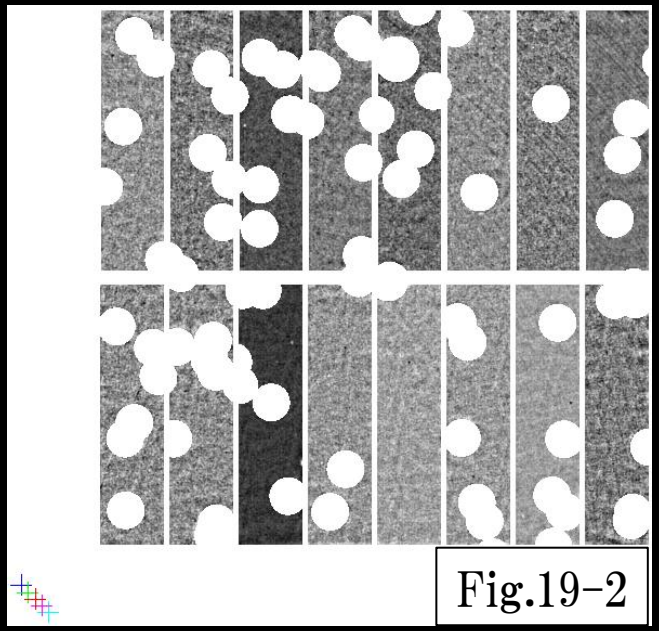


Fig.19-2

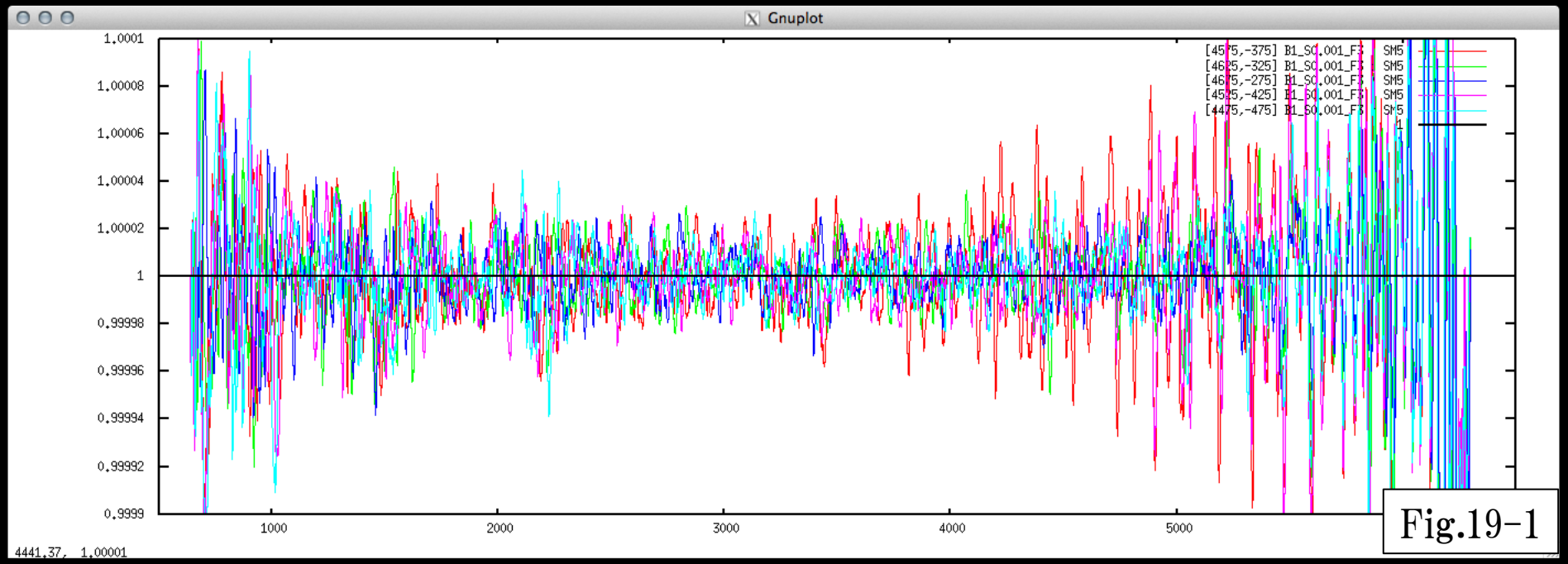



Fig.19-1

# Determining Tree Ring Center

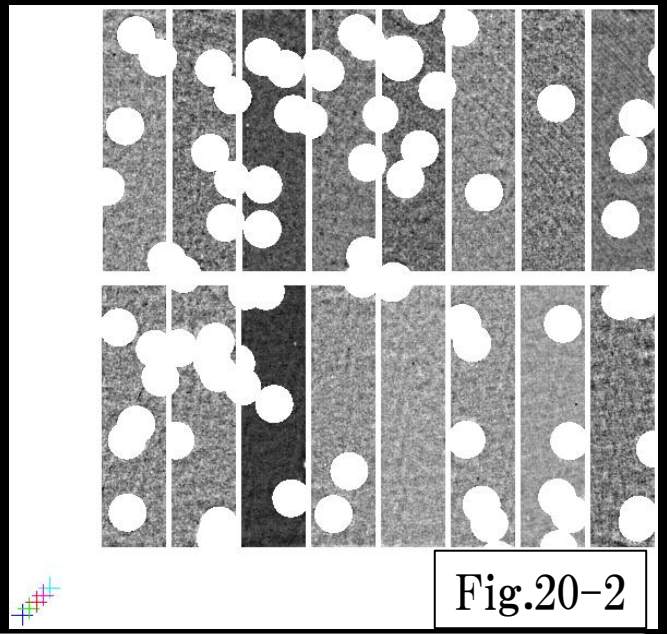


Fig.20-2

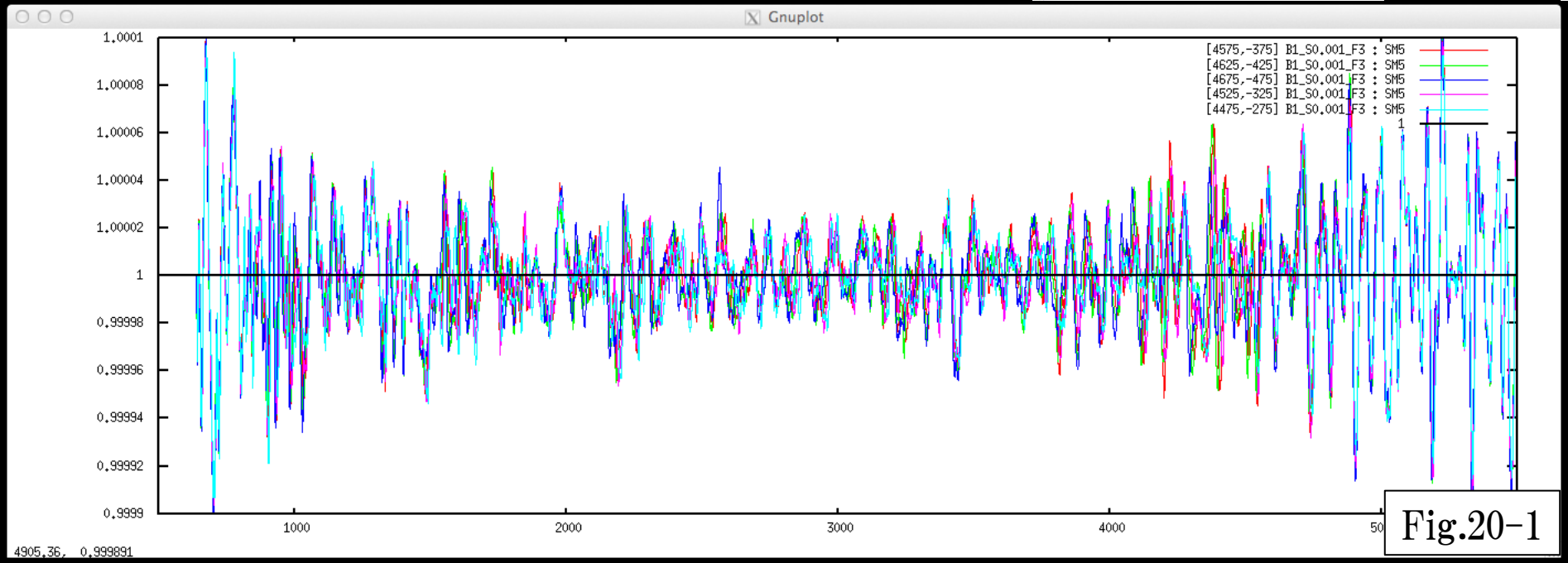



Fig.20-1

# Determining Tree Ring Center

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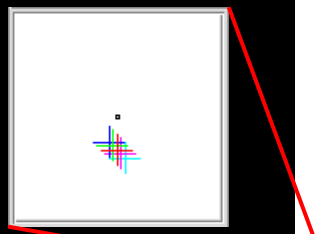


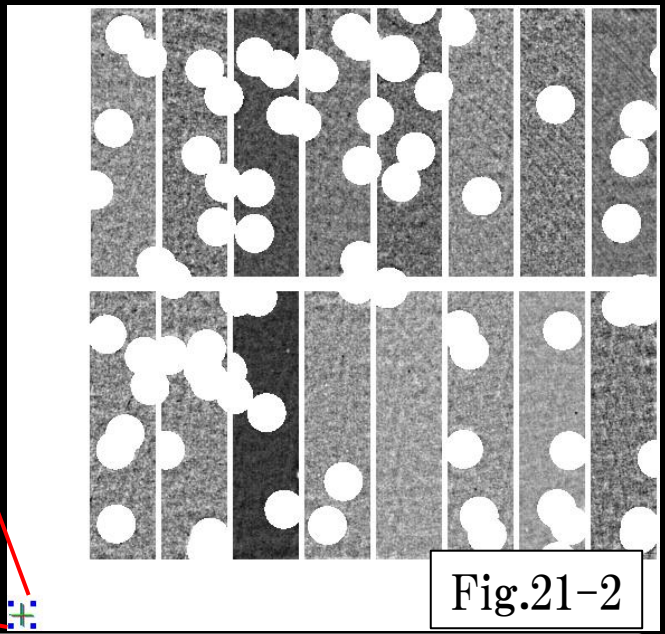


Fig.21-2

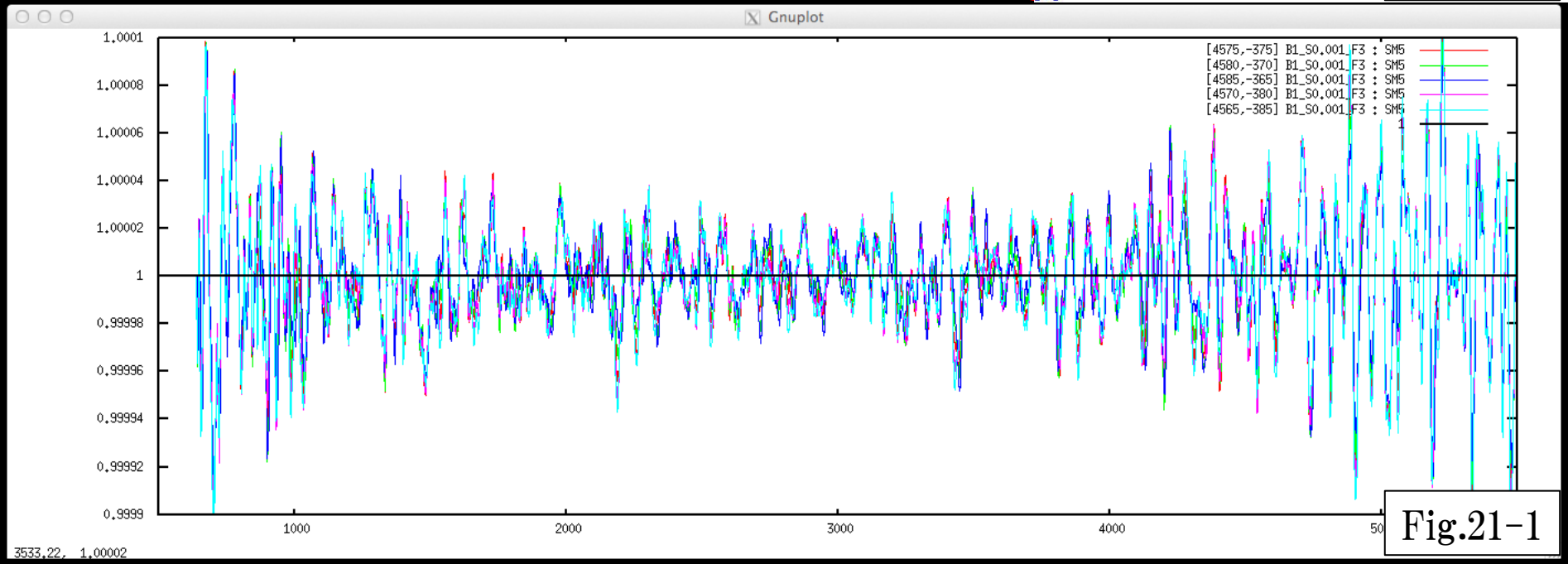
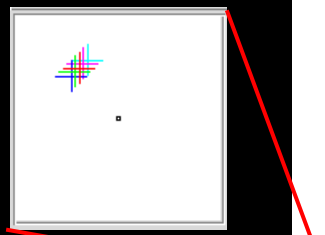



Fig.21-1

# Determining Tree Ring Center

- 



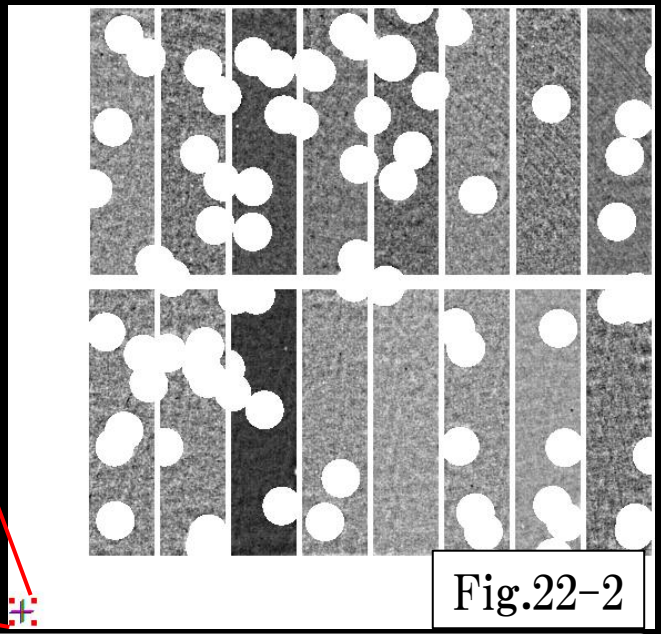


Fig.22-2

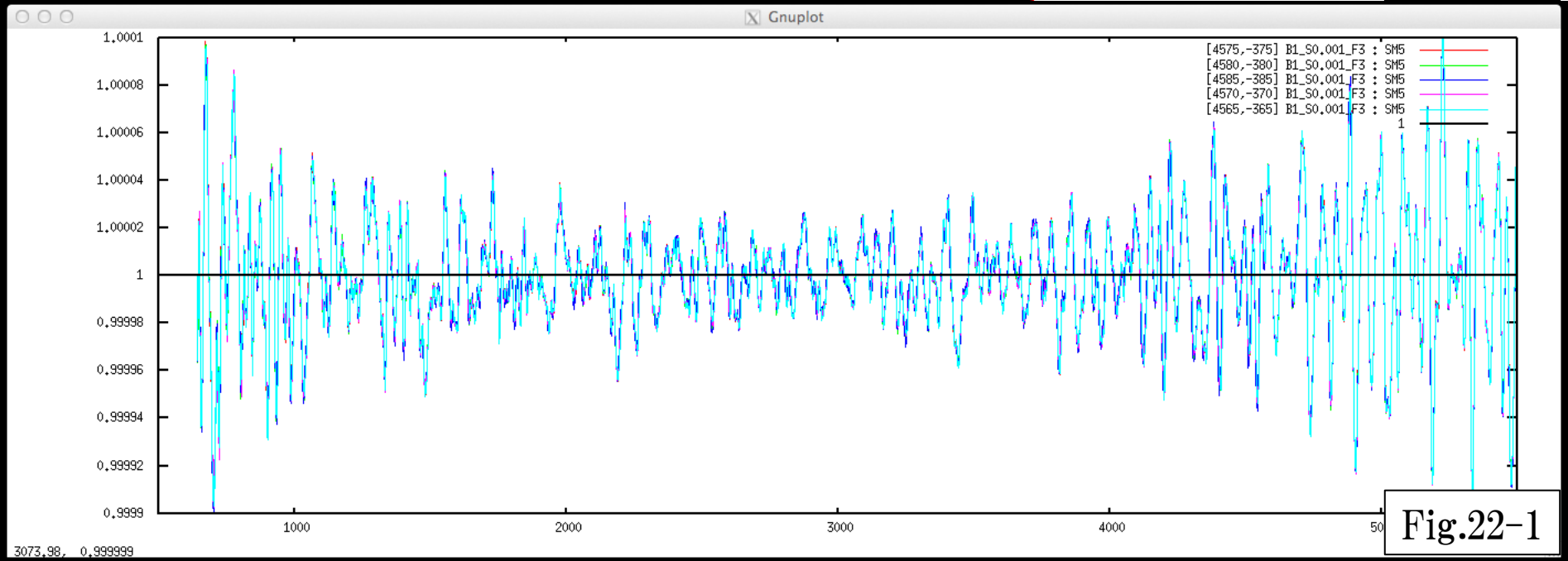
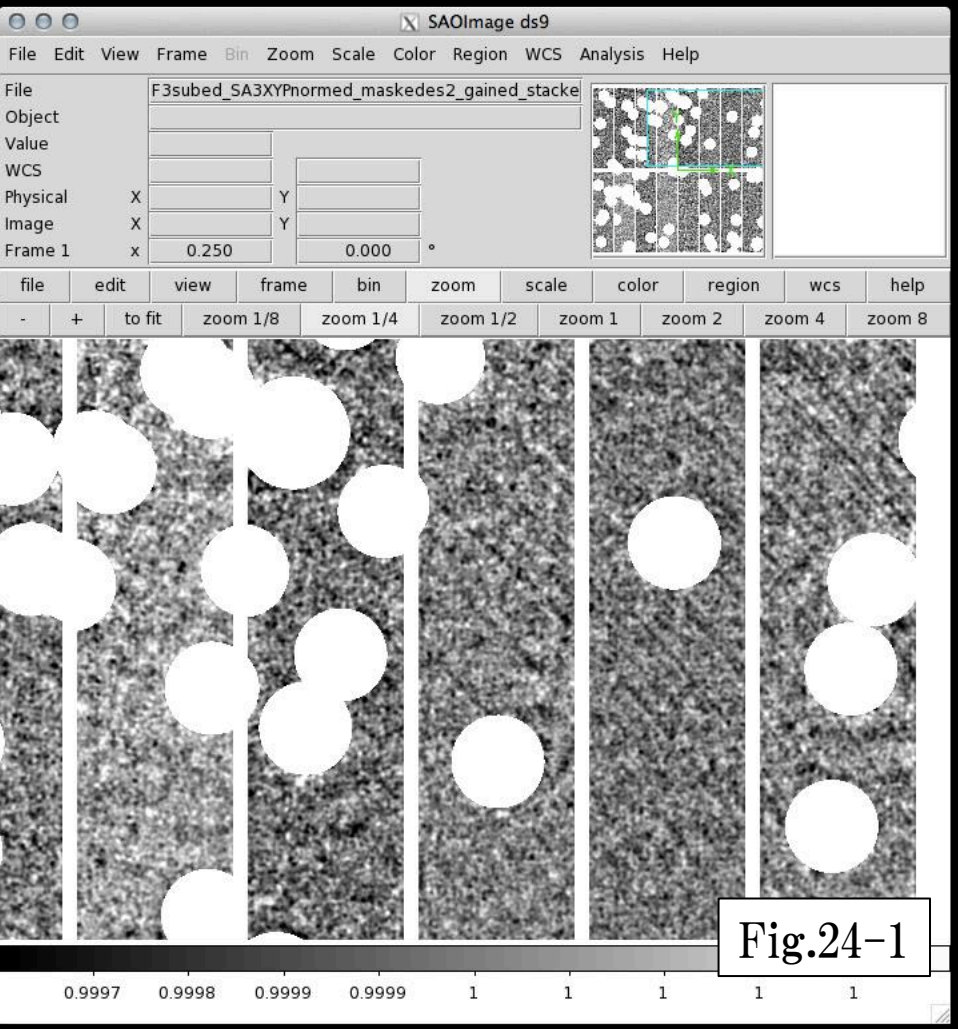
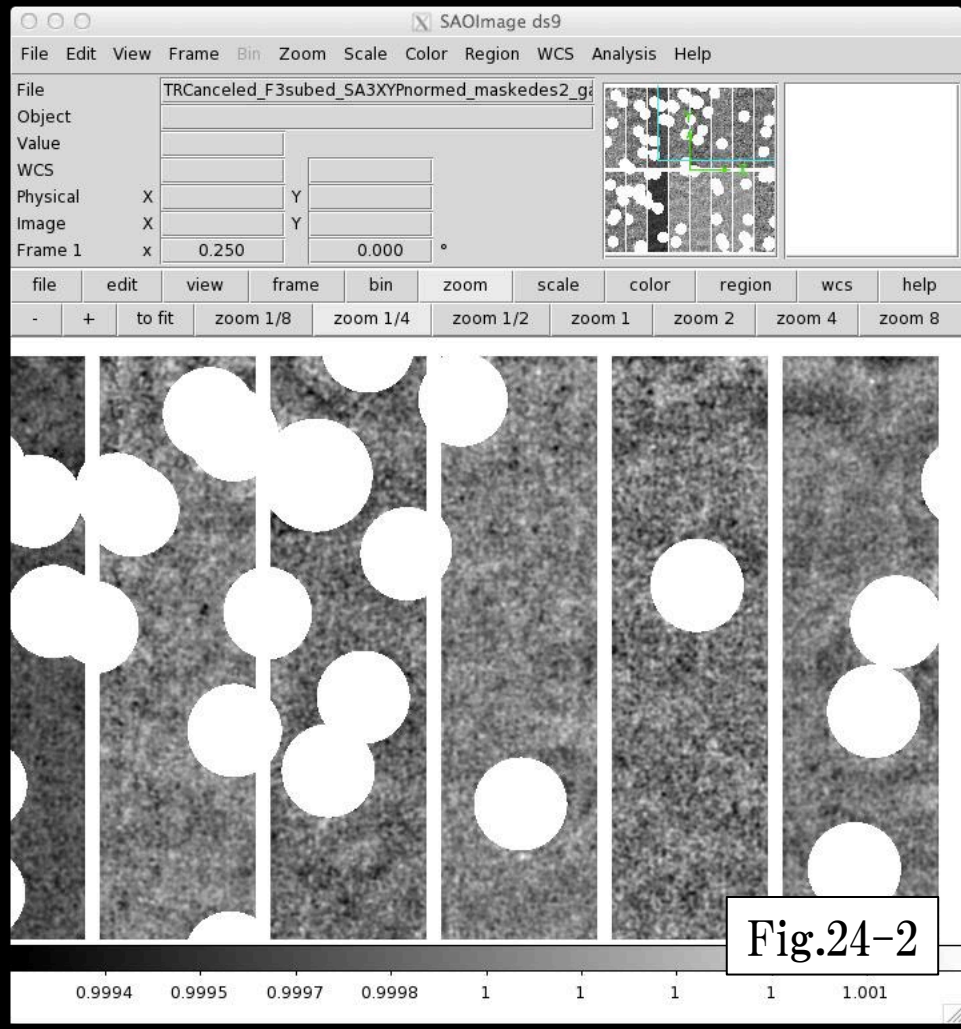



Fig.22-1

# Testing Tree Ring Cancelation




Before Cancelation (Smoothed image)




After Cancelation (Smoothed image)

# Measuring Tree Ring Pattern

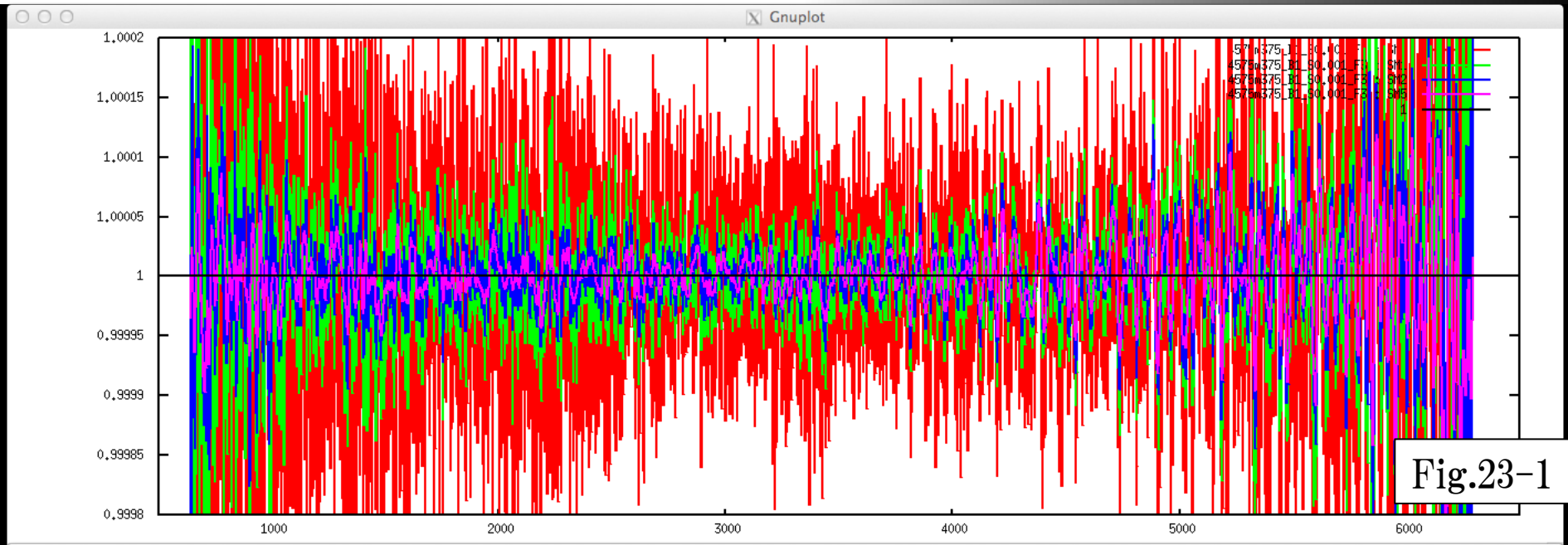



Fig.23-1

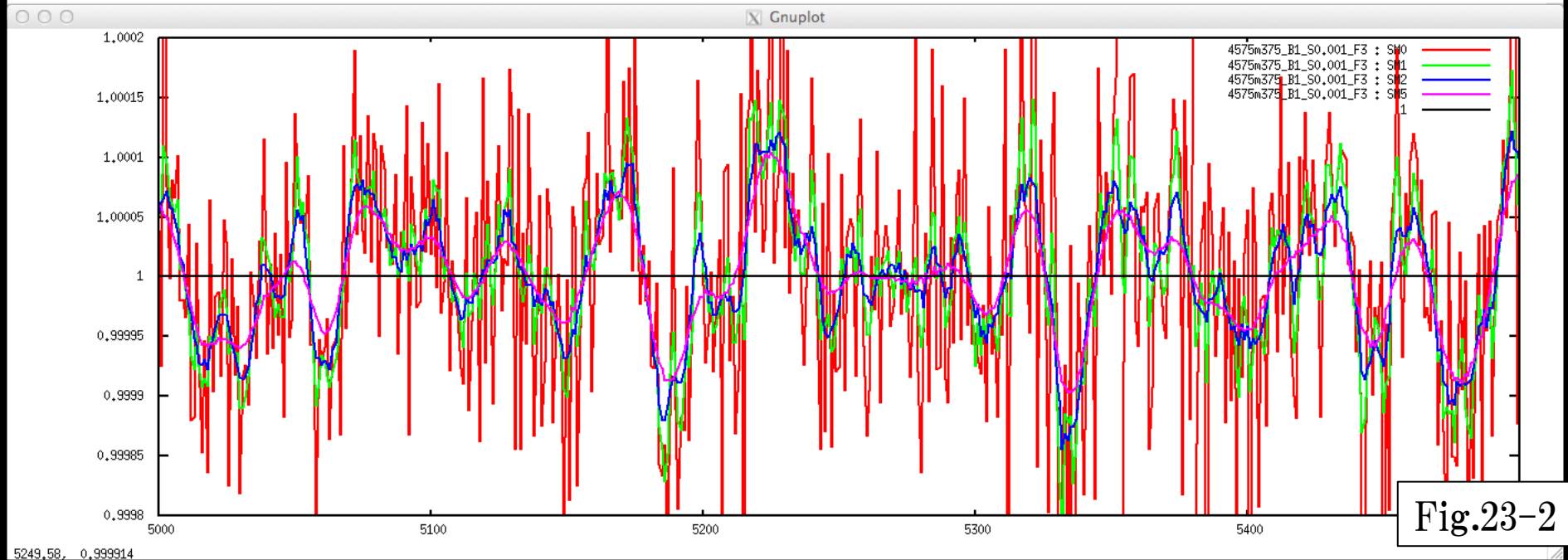



Fig.23-2

# Calculating Displacement by Tree Ring

Andres's equation for estimating displacement from tree ring effect for flat.

$$f(r) = \frac{1}{r}\int rw(r)dr$$

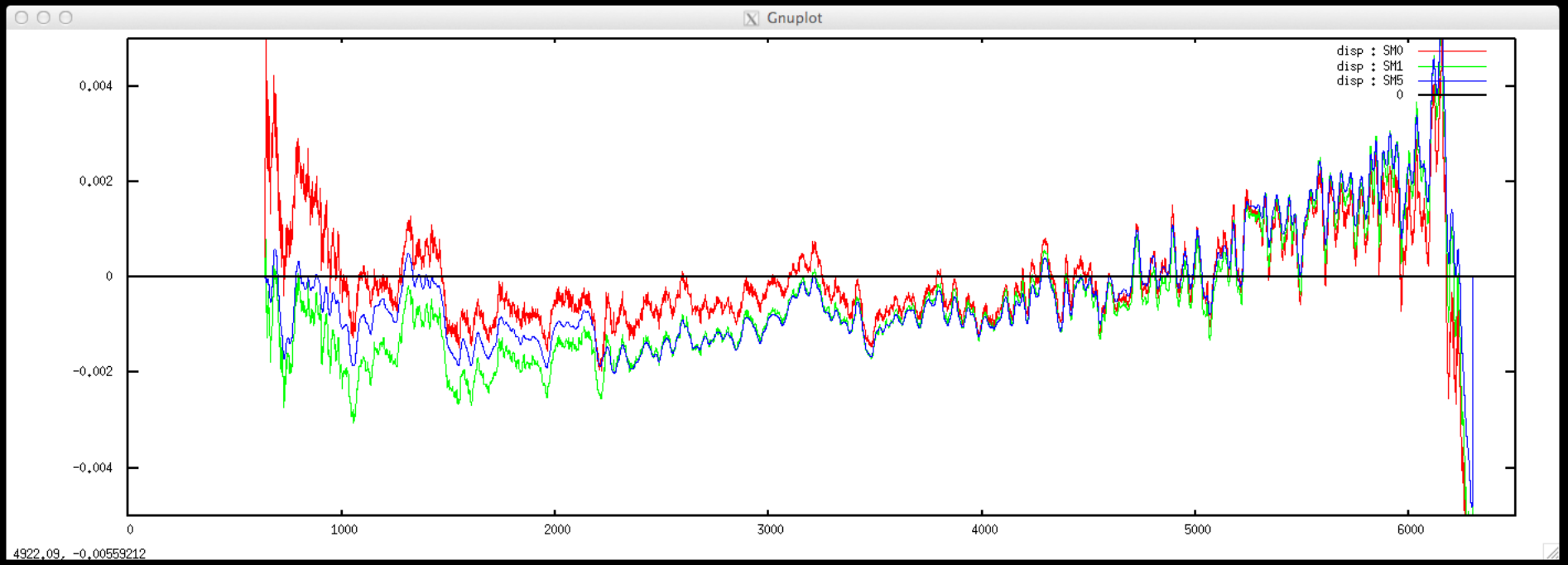



Fig.25

# Calculating Spurious Shear by Tree Ring

A formula for estimating spurious shear from concentric displacement

$$\kappa = \frac{1}{2}\left(\frac{\partial f(r)}{\partial r} + \frac{f(r)}{r}\right)$$

$$\gamma = \frac{1}{2}\left(\frac{\partial f(r)}{\partial r} - \frac{f(r)}{r}\right)$$

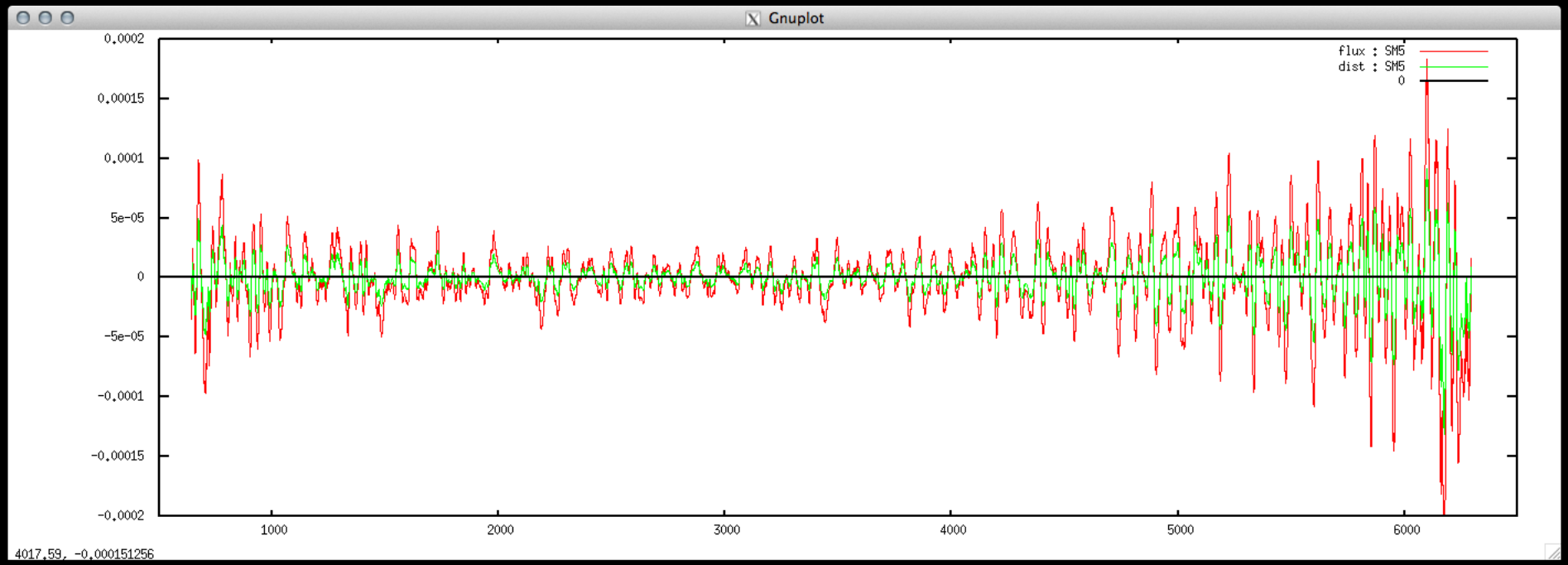


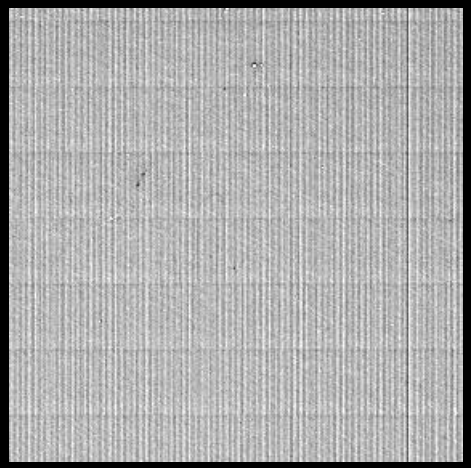

Fig.26

# Tree Ring on LSST CCD

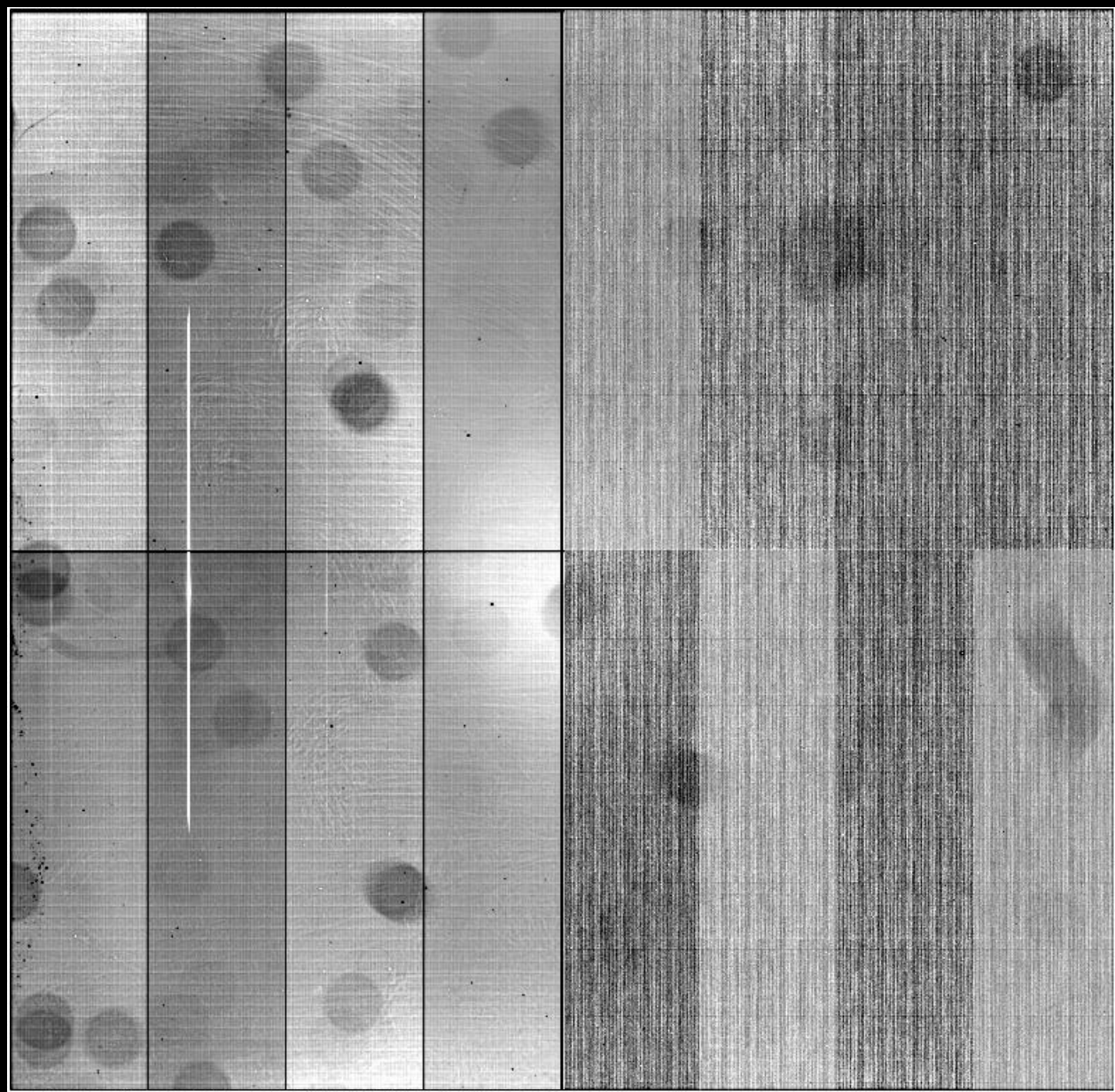
- ITL CCD

- wave length 750nm
Shorter wave length images have stronger strange pattern.
Longer wave length images have stronger fringes.

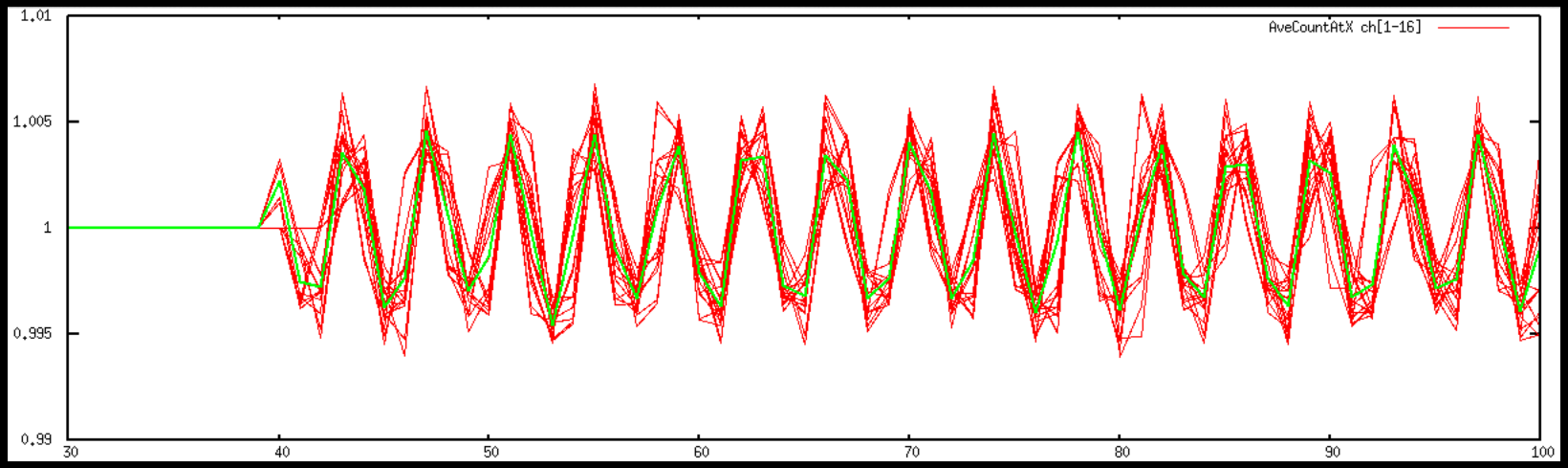
- Almost same steps as e2cv CCD, except correcting bamboo patterns.



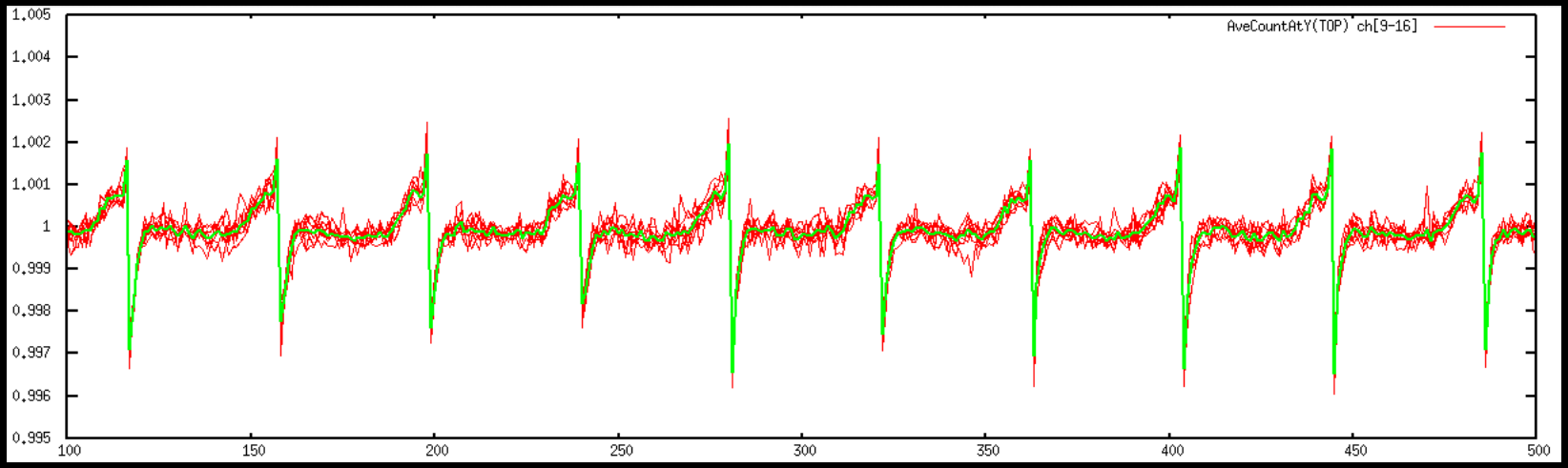
Bamboo pattern



# Correcting Bamboo Pattern

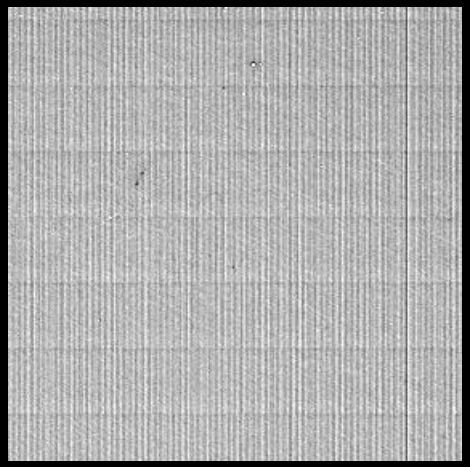



Average counts vertical lines

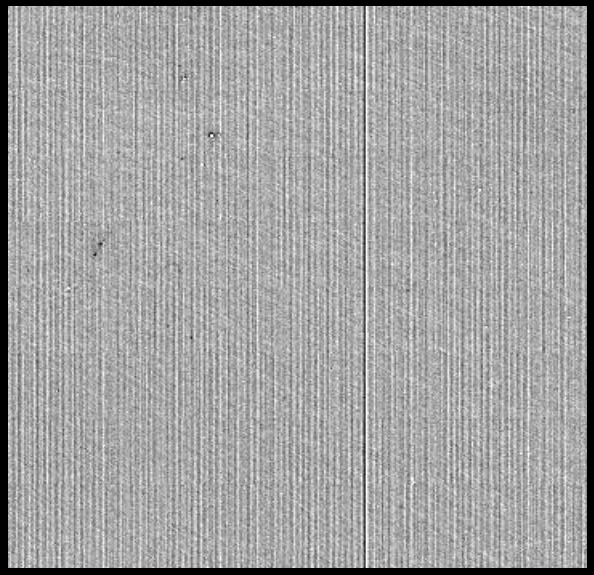



Average counts horizontal lines

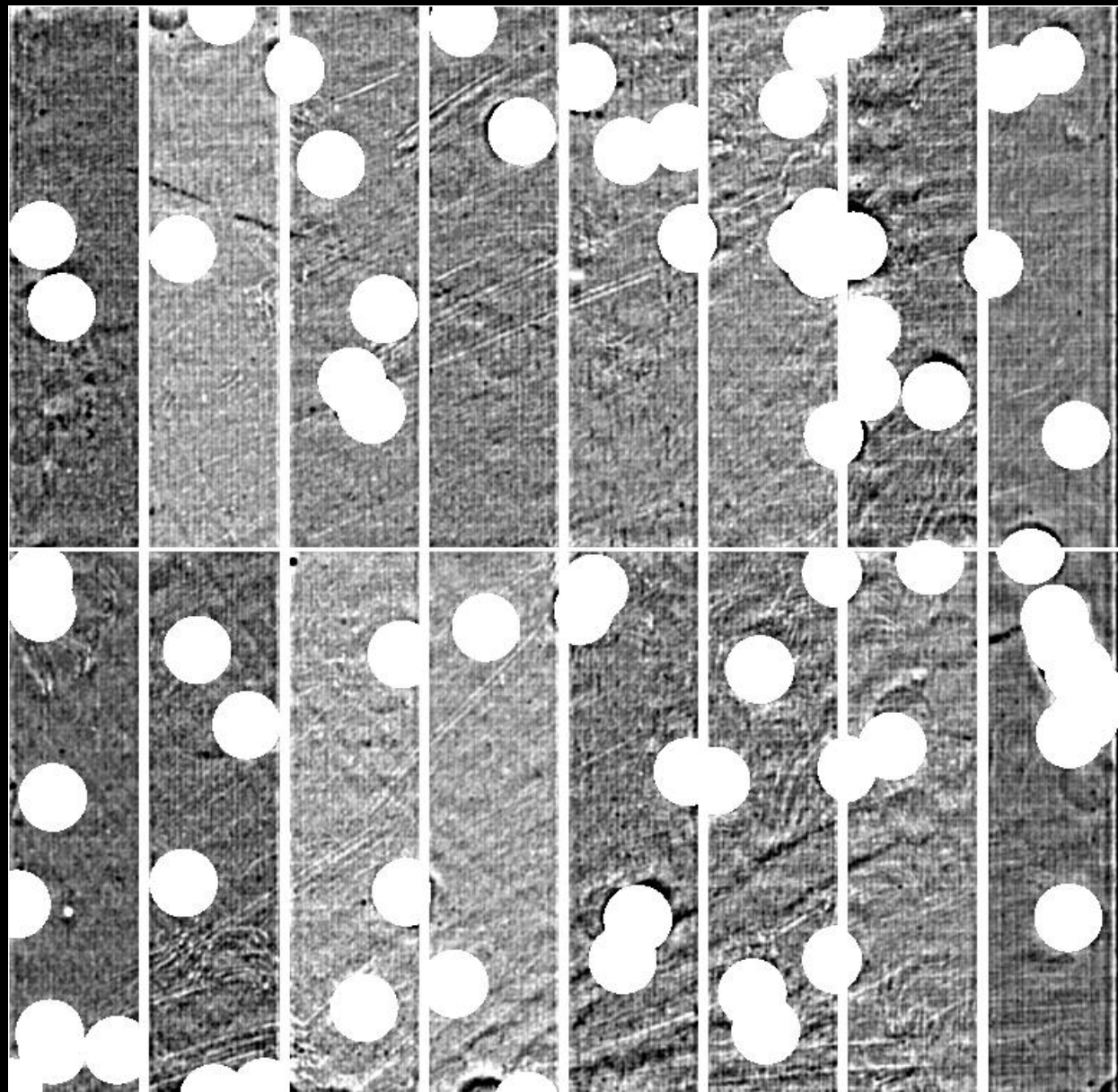
# Correcting Bamboo Pattern



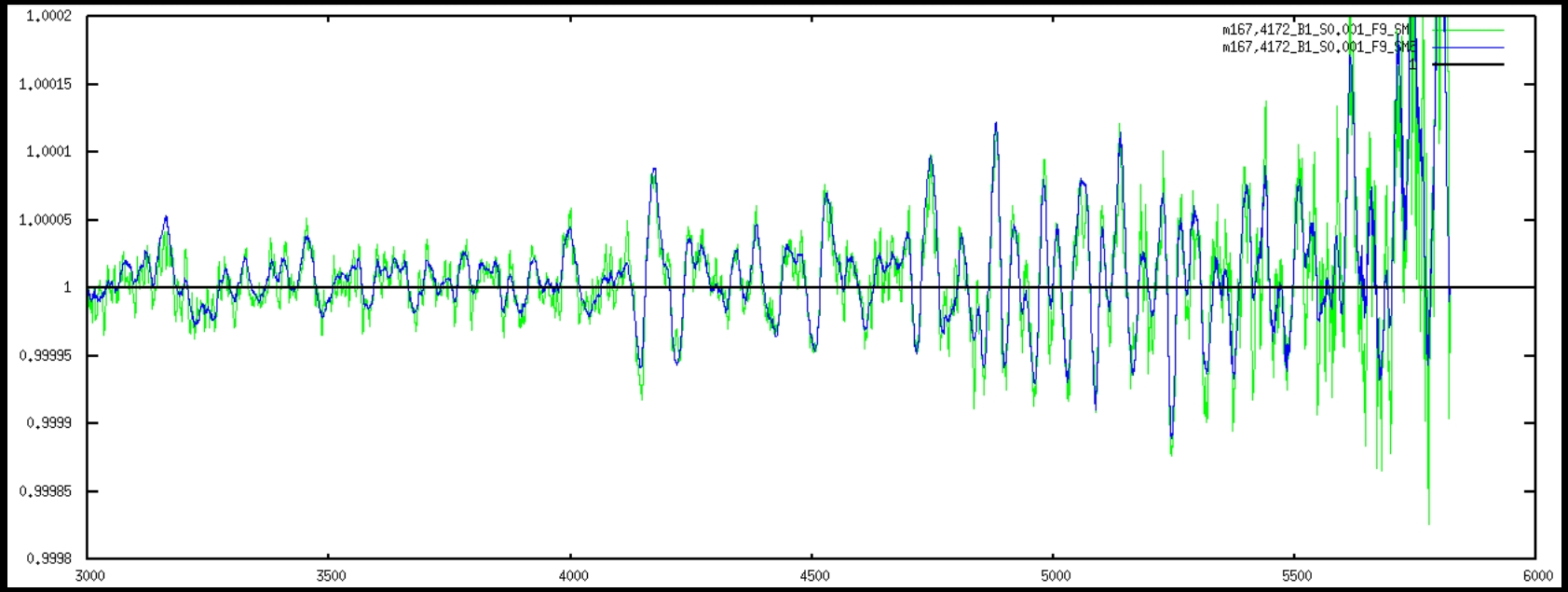
Bamboo pattern



Corrected Bamboo



# Tree Ring on LSST CCD




Conclusion

I measured the tree ring pattern on two LSST CCDs. There still are some issues for more precise measurement, determination of the center, removing noise peaks and so on. However, the results are enough to estimate typical scale of the tree ring pattern. The estimated scale is 0.01% for flux fluctuation, 0.001 pixel for displacement and 0.005% for spurious shear from both CCDs. These are 1/50 scale of them of DEC and small enough to be ignored.

# Tree Ring on LSST CCD